HYDROLOGICAL SURVEYS FOR THE LOCUST
POINT POWER PLANT
PART 1. GENREAL STUDIES

John C. Ayers and Robert F. Anderson

1969 Spec. Rep. 41

HYDROLOGICAL SURVEYS FOR THE LOCUST
POINT POWER PLANT
PART II. CURRENTS AND DILUTION

John C. Ayers and Robert F. Anderson

1969

HYDROLOGICAL SURVEYS FOR THE LOCUST
POINT POWER PLANT

PART III. PRELIMINARY BIOLOGICAL,
FISHERIES, AND RADIOLOGICAL STUDIES.

John C. Ayers, Robert F. Anderson, Norbert W.
O'Hara, Dean E. Arnold, and Charles C. Kidd.

1970

Part IV. The 1969 phytoplankton collections in the Locust Point region. John C. Ayers, Robert R. Anderson, Norbert W. O'Hara. 1970

HYDROLOGICAL SURVEYS FOR THE LOCUST POINT POWER PLANT

PART 1. GENERAL STUDIES

John C. Ayers
and
Robert F. Anderson

Under contract with
The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

1969

THE GENERAL AREA

From the mouth of the Detroit River southwestward to Toledo on the mouth of the Maumee River at the western tip of Lake Erie, thence generally southeastward to and beyond Port Clinton, Ohio, the land is the bottom of ancient Lake Maumee; it is low, flat, and virtually featureless. This topography continues for miles inland in the sector from southeast to northwest of the lake shore.

Because of the low land upwind to the prevailing winds, the western basin of Lake Erie is well ventilated. Winds from the north, east, and south quarters are less frequent than winds from the southwest to northwest, but they do occur. It is probably in response to wave-activated sand movement during storms from these directions that most of the western and southwestern shores of Lake Erie have barrier beaches of greater or less extent and degree of development. Between the barrier beaches and the mainland, lie marshes of various extents and degrees of inundation. Tributary rivers and streams entering the western basin of Lake Erie are multi-branched and of low gradient; they and their branches contribute to the extent of the marshes behind the barrier beaches.

Culturally, the lake shore in this part of the western basin of the lake is dominantly of farmland and shore summer cottages with a minor portion occupied by the cities of Monroe, Michigan, and Toledo, Ohio. Port Clinton, Ohio, at the eastern edge of the area of interest, has about 6,000 inhabitants.

Though obviously under the control of man, the barrier beaches and the edges of the mainland tend to a rank growth of trees, shrubs, and vines. Marshes behind the barrier beaches range from small cattail marshes rimmed by trees, to very extensive lagoons edged by rushes, cattails and other marsh plants. Most of the larger marshes are dissected by dikes, causeways, and

canals created by previous owners (many of whom were hunting clubs). Most of the large marsh areas are now wildlife refuges maintained by the State of Ohio or by the federal government.

On the southwestern shore of the western basin of Lake Erie, Locust Point is a minor protuberance where the trend of shoreline changes from generally southeast. From Toledo to Locust Point is about 22 miles along the shore; from Locust Point to Port Clinton is somewhat less than 10 miles along shore.

BOTTOM SEDIMENTS OF THE LOCUST POINT SITE

In this section we follow the reconnaissance survey of bottom sediments that has been carried out in the western basin of Lake Erie by the Ohio Department of Natural Resources beginning in 1956 and supplemented by local studies since then (State of Ohio 1957). The findings of this survey are shown in Figure 1. They have been checked and confirmed by our own observations on an opportunity-offers basis during our own studies. We have found nothing that causes us to doubt any of the conclusions of the Ohio survey.

According to the Ohio survey and our own observations, the shore from Little Cedar Point at the east edge of Maumee Bay to Port Clinton east of the plant site is of low elevation and comprised of sand overlying a stiff lake-clay. In the Locust Point area the beach and back-beach are of sand with shell admixed. The underwater bottom immediately off shore along the plant site is predominantly of sand with some shell and mud intermixed. This sandy bottom shallowly overlays stiff lake clay and varies from 3/16 mile wide at the west edge of the plant property to 1/8 mile wide at the east property line.

Offshore of the sandy-bottom belt is a dominant band of the stiff lake clay, presumably exposed by wave action, and varying in width from 3/8 mile

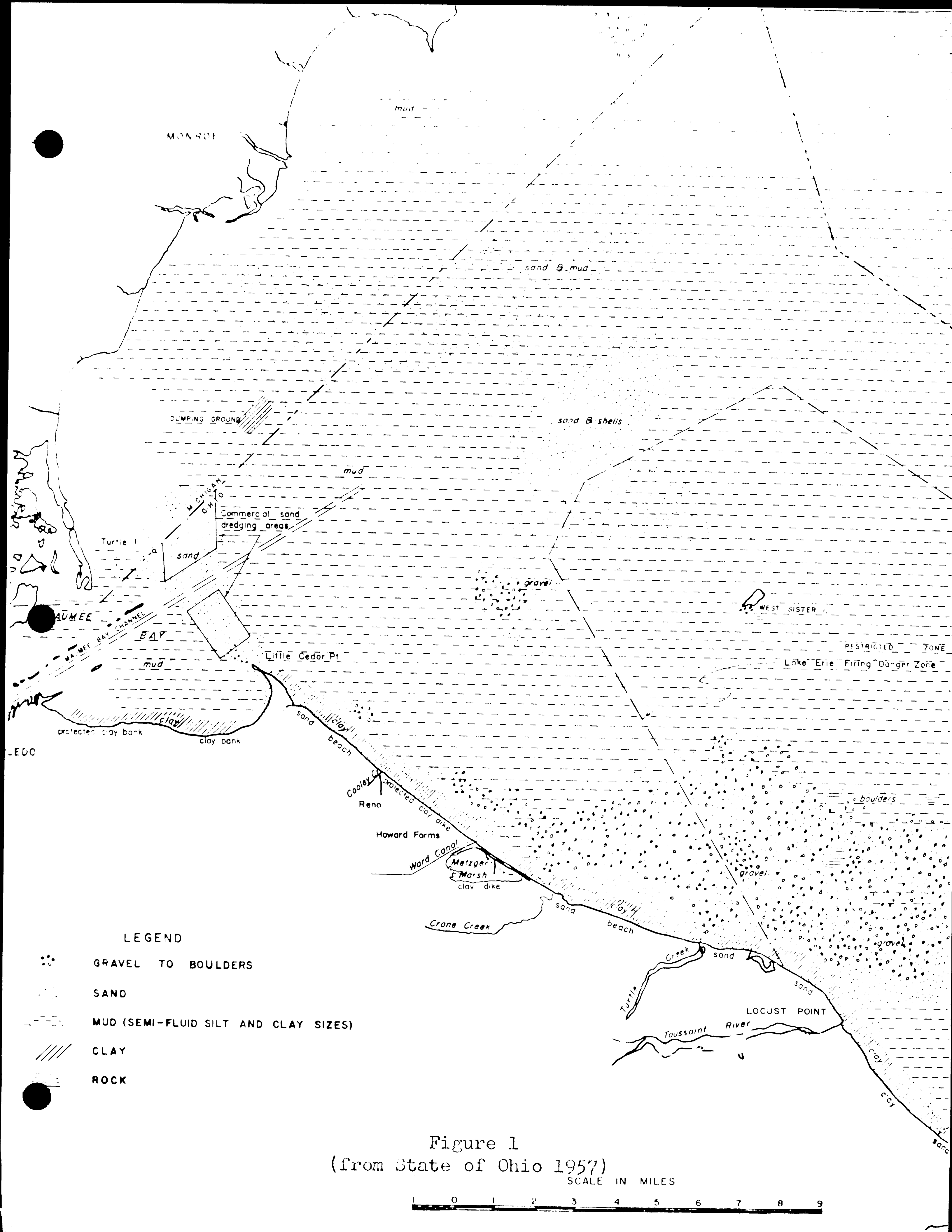


Figure 1
(from State of Ohio 1957)

near the west side of the plant property to 1/4 mile at the east edge of the property.

Off the western side of the plant property the bottom at about 9/16 mile becomes sand with increasing amounts of gravel as one goes further off shore. Eastward of about the middle of the plant property the offshore deposits become dominantly muddy sand. Offshore bottom sediments dominantly of mud do not begin until the mouth of the Toussaint River has been passed going eastward.

In the far-offshore area, 3 to 8 miles, there are four small areas of bedrock, each less than a mile in any dimension, located off the west and central parts of the plant property. No such reefs are situated off the east side of the plant property. These reefs are important in the local fish ecology as spawning grounds; they are, however, not apt to be reached by the plant effluent which should travel eastward.

Beyond these reefs, to the International Boundary at more than 15 miles, the bottom is of mud.

POSSIBLE SHORE EROSION EFFECTS OF THE INTAKE STRUCTURE

It is noted that the sheet-pile-and-fill structure protecting the plant's intake channel will extend lakeward from shore at nearly a right angle. The shore throughout the Locust Point property is primarily of sand overlying stiff lake clay (State of Ohio 1957).

Hartley (1964) and Braidech (1969; personal communication, Appendix A) both indicate a southeastward movement of sand in the littoral drift from Locust Point toward Port Clinton. Both Braidech and the U.S. Lake Survey charts indicate that west of Locust Point the net littoral drift is westward; the charts show sand collection on the east sides of groins and jetties.

These sorts of information confirm the findings of Hartley, Herdendorf and Keller (1966) that the current of the Detroit River crosses the western basin of Lake Erie and divides into eastward and westward flows at Locust Point. Drift card studies by Olson (1951), as reported by Hutchinson (1957), indicate an oscillatory current off Locust Point. Braidech, correctly, we believe, points out that winds from east to northeast have a longer open-water fetch bearing upon Locust Point, and that wave-generated littoral currents to the westward might be dominant (however slightly) over eastward littoral drift generated by waves under the prevailing SW winds that have relatively little fetch before Locust Point.

We believe that Olson's deduction of oscillatory currents off Locust Point is a reflection of the fact that his cards were in general far enough off shore for the hydraulic pressure of the outflow of the Maumee River to have cancelled the effect of the longer fetch available under easterly winds.

From the total of the evidence available we cannot say that the intake structure will capture littoral sand from the east or the west, in all likelihood it will capture sand from both directions. It is certain that the State of Ohio will oppose any capture of sand that would interfere with the natural littoral transport of sand and hence result in beach-building or shore erosion.

We recommend that the intake structure be equipped with a facility for the pumped by-passing of sand in either direction. Unfortunately there appear to be no data on the size of littoral transport of sand. It appears that the by-pass mechanism need not be excessively large, but that it should be capable of being run in either direction.

WATER DEPTHS OFF THE PLANT SITE

During the first two weeks of October 1968 a detailed survey of water

depths off the plant property was carried out. The entire frontage from west of the west property line to east of the east property line was measured and used in constructing baseline segments. The centerline of the access road running out to the beach near the west end of the property was used as the reference; this road is shown in Figure 2 by two parallel lines near the west boundary. From the road centerline projected to the beach, all the beach front was measured by steel tape into six straight-line segments each with a transit station at each end. All the baseline segments were related to each other, and hence back to the access road centerline, by forward and back azimuth angles.

Soundings were taken by an outboard launch carrying a Raytheon portable recording fathometer. Sounding lines were run from 12 feet of depth-of-the-day toward shore along parallel courses approximately to the southwest along visual bearings provided by portable range targets set one on the water's edge and the second as far back on the backbeach as possible. The launch, operating at constant rpm, kept the range targets aligned as it came inshore. At the start of each sounding line the launch raised a fluorescent orange flag, and continued to do so at one-minute intervals during its run toward shore; when it was aground on the beach the flag was raised a last time regardless of time since the last raising.

At each raising of the flag, the fathometer record was marked and the two transit-men recorded true-compass azimuth angles to the flag from the ends of the known-position baseline segment in use. Fixes during the sounding runs ranged from nine to sixteen. Between sounding-line runs the portable range markers were moved forward by equal steel-taped distances parallel to the baseline segment in use.

In the region of the proposed intake channel near the west side of the property sounding lines were run on 100-foot spacings. Between the region

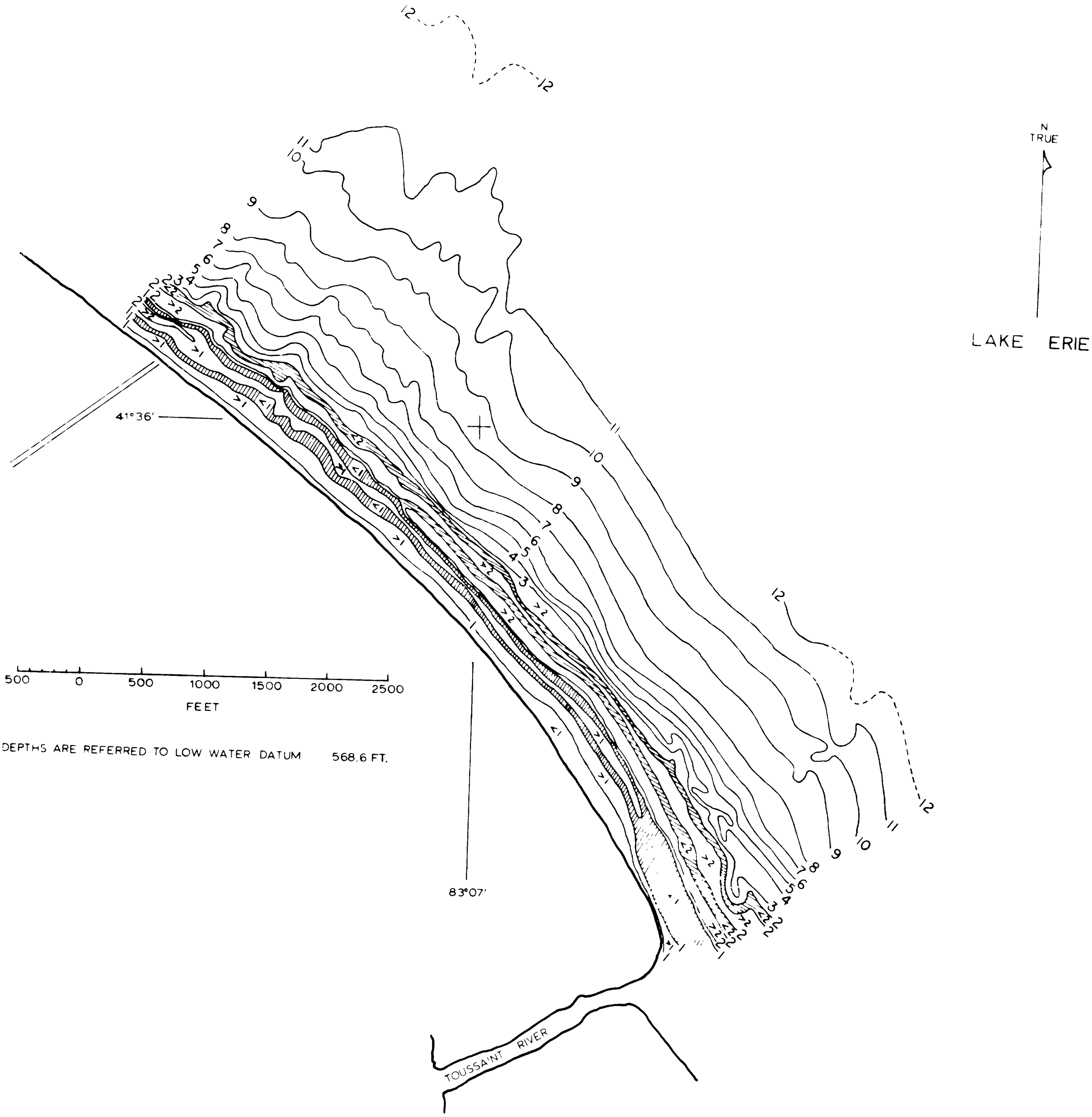


Figure 2

Water Depths off Locust Point, October 1968.

of the intake channel and the outflow channel the spacing between sounding lines was opened to 200 ft and then to 400 ft; as the outfall region was approached the spacing of sounding lines was reduced to 200 ft and then to 100 ft. Heavy amounts of detail in the intake and outfall regions were thus obtained.

Corrections applied to the raw depth records to bring them to lake datum were the algebraic sums of: monthly mean lake level above datum, the stage of the daily seiche activity (including wind effects), and the depth of the fathometer transducer below water surface. Because a local water-level gauge at Anchor Point (Turtle Creek) was a research gauge not referenced to real lake level, it was necessary to refer the correction factors for seiche activity and monthly mean above datum to the Toledo gauge where both are magnified by the pointed lake-end to greater values than apply at Locust Point; the final corrected depths shown for Locust Point in Figure 2 are, therefore, ultraconservative: there is somewhat more water depth at Locust Point than the Figure shows.

Contouring of depth done in Figure 2 is ordinary contouring -- each contour line connects the most inshore occurrences of that depth. This is not the ultraconservative contouring employed (for navigational safety) by the U.S. Lake Survey, who traditionally draw each depth contour *outside* the *outermost* occurrences of that depth.

There are in the finished survey shown in Figure 2 three matters worthy of comment. Deeper water comes closer to shore off the eastern two-thirds of the plant property. Comparison to U.S. Lake Survey boat-sheets of 1962-65 show that there has been erosion off the region of the proposed intake channel and water depths there are deeper than formerly. The presence of three (or four) sand bars parallel to shore and close to the beach indicates a predominance of currents parallel to the beach; the fusion of the two innermost

sand bars into a sand flat off the eastern end of the plant property probably is an expression of some interference with the alongshore currents by the discharge of the Toussaint River.

At both the western and the eastern ends of the plant property, dashed portions of the 12-foot contour are estimates based on solid values of 11.75 to 11.98 ft just inshore of them.

TEMPERATURE PROFILES IN WESTERN LAKE ERIE

Temperature profiles in western Lake Erie are relevant in connection with the Locust Point plant in that they have bearing upon the temperature of water entering the plant intake channel. During seasons other than summer the lake water is cold enough to be an efficient cooling medium, in summer the warm lake water is less efficient in cooling and plant operating plans may need to be modified by pumping more water during this season.

According to present plans the intake channel will be open to the lake at 10 feet of depth below Low Water Datum at its lakeward end and will deepen to 12 feet after the intake channel crosses the lake beach.

In this study we have drawn upon the records of 250 selected temperature soundings made by bathythermograph in western Lake Erie and in the island region by the State of Ohio, Department of Natural Resources, Division of Geological Survey (Herdendorf 1967) and by the Canadian Coast Guard Ship PORTE DAUPHINE (Rodgers 1962). The two sources contain data for the years 1952, 1953, 1954, 1963, and 1966 from Ohio and for 1961 from the Canadians. The selected records cover the months May to November inclusive.

The criteria involved in the selection of the records used were: 1) only records from the shallow island-region and the shallow west end of the lake west of the islands were used because the Locust Point will draw water from

the shallow west end of the lake; 2) records from Maumee Bay and the Detroit River were included in those selected because the Locust Point region is affected by both these sources of influent water (Hartley, Herdendorf, and Keller 1966); 3) records from stations less than 10 feet deep were eliminated because water so shallow could show supratypical warming or cooling not applicable to the Locust Point intake; and 4) records from stations deeper than 35 feet were eliminated because these deeper waters might show subtypical warming or cooling not applicable to the Locust Point intake.

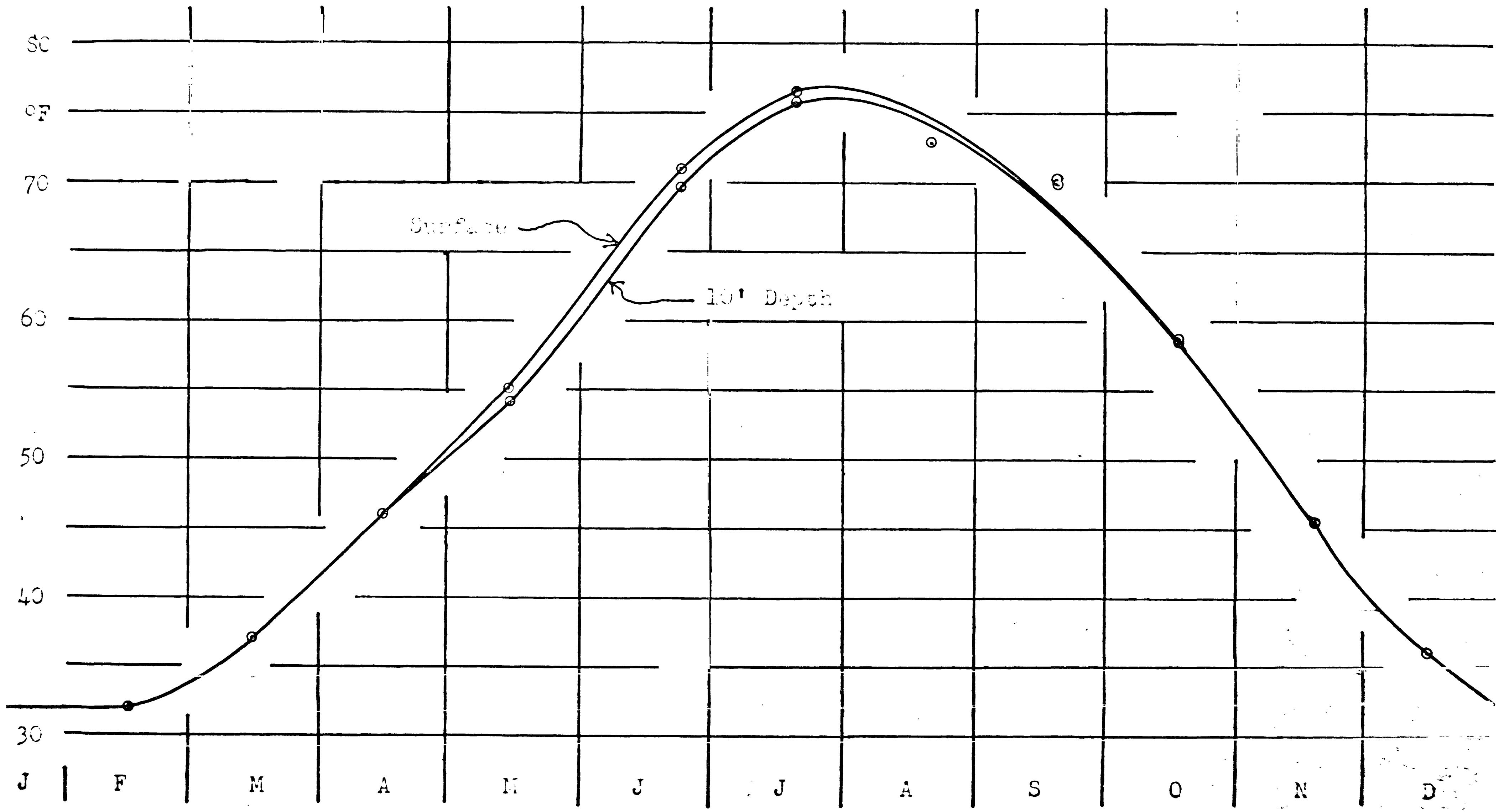
To eliminate so far as realistically possible any spurious temperature effects from diurnal temperature cycles and from shallow floating water masses from local streams, we have worked out from the 250 selected temperature soundings the monthly mean temperatures at 10 feet of depth for May through November. Monthly mean increments of temperature of surface water over temperature at 10 feet were worked out and added to the 10-foot temperatures to obtain monthly mean surface water temperatures.

For the months of January and February, when ice can be considered to be present, 32°F was used for both depths. For the months of March, April, and December, when the west end of the lake is isothermal from surface to bottom, we have used data from the Collins Park Water Treatment Plant at Toledo. The Toledo intake is at 22 feet.

The monthly mean data derived from the selected bathythermograph soundings were plotted on the day of the month determined by weighted average of the numbers of observations made on different days of the month. Data from other sources are plotted at mid-month.

The resulting data, basic to the two temperature curves shown in Figure 3, are presented in Table 1.

It is evident that water of mean temperature over 75°F will be drawn by the intake during much of July and August. Whether or not increased cooling



Annual Cycle of Water Temperature at Surface and 10 Feet of Depth, 10'-35' Stations Only.

Figure 3

Table 1. Monthly mean water temperatures in 10-35 feet in western Lake Erie.

Month	No. of Stations	Weighted Mean Day of Month	Mean 10-foot Temperature	Mean Delta-T, 10'-to-Surface	Mean Surface Temperature
January*	--	15th	32.0°F	0.0°F	32.0°F
February*	--	14th	32.0	0.0	32.0
March**	--	15th	37.0	0.0	37.0
April**	--	15th	46.0	0.0	46.0
May	32	14th	54.2	0.9	55.1
June	99	23rd	69.7	1.3	71.0
July	31	20th	75.9	0.5	76.4
August	6	21st	72.7	0.0	72.7
September	7	19th	69.7	0.4	70.1
October	45	17th	58.5	0.1	58.6
November	30	18th	45.4	0.0	45.4
December**	--	15th	36.0	0.0	36.0

* Ice presumed present

** 1966 data of Collins Park Water Treatment Plant, Toledo

water pumpage during this period would be desirable will be a company decision.

MAXIMUM VARIATIONS IN LAKE ERIE WATER LEVEL

The maximum and minimum expectable levels of Lake Erie in the region of the plant are of concern for two reasons: one is the height of water against which the plant must be protected from flooding during high water; the other is whether the depth of intake channel is such as to insure that condenser cooling water will be available during low water.

Water levels in the western basin of Lake Erie are affected by a number of more or less cyclic variations. During the 107 year period of record the lake has exhibited a long-term variation in level, going from below datum to above datum over a period of several years and falling slowly to below datum again during the ensuing several years. The maxima of the long-term variation are: nearly 4.2 feet above datum in May 1952, and nearly 1.2 feet below datum in February 1936.

The lake undergoes an irregular annual variation in level, with high levels in summer and low levels in winter. Over the period of record the total annual fluctuation has ranged from 2.75 feet to 0.87 feet, but the average annual cycle involves a 1.2 foot change in level.

Next shorter in period are the wind tide (wind setup) caused by storm winds blowing along the length of the lake, and the main uninodal lengthwise seiche of the lake which is set in motion when storm cessation releases the wind setup and allows it to slosh back and forth along the length of the lake in an oscillating motion. The wind tide requires several hours to fully develop and is several feet in height; the main uninodal seiche has a period of 14-15 hours and a height of 2-4 feet.

A smaller seiche in the west end of Lake Erie oscillates between the northern and southern shores. It is (Hunt 1959) produced by the southerly winds that normally preceed the major WSW storms which produce the great wind tides. These southerly winds produce a setup on the Canadian shore west of Point Pelee and, as the wind shifts, the setup is freed to oscillate as a transverse seiche in the western basin of the lake. Hunt gives this seiche an amplitude of 0.8 foot above and below mean lake level.

Irish and Platzman (1962) investigated the possibility that there might be storm surge activity generated by resonant coupling between a basic mode of the lake and the speed of frontal passages across the lake. They say (page 45), " We should also mention in this connection that a study was made of frontal speeds in an attempt to establish a relation between set-up magnitude and propagation speed of the front in its passage across the Lake. This was motivated by the fact that the propagation speed of free long waves on Lake Erie, corresponding to the mean depth of the Lake, is about 25 to 30 knots, so that resonant coupling with a frontal system might be conjectured. Careful estimates of frontal speeds were made, for the period of transit of the front across the Lake, in more than 20 cases in which set-up ranged from 6 to 13 feet. *The data did not, however, exhibit any relation which would support the idea that resonant coupling is a significant factor in determining set-up magnitude*. The result was corroborated by an independent analysis of the response of a one-dimensional lake to a moving stress band of finite width. *The latter analysis* (to be presented elsewhere) *confirmed that resonance is almost completely suppressed when the stress-band width is greater than the length of the lake*, as would be the case for Lake Erie, the major axis of which is about 350 km. in length." The italics above are ours. The later report referred to above is Platzman (1966, page 2480).

The lengthwise setup or wind tide produces the greatest disturbance of water level. The water level gauging station at Toledo is the major gauging station nearest the plant site. U.S. Lake Survey records of instantaneous maximum and minimum water levels at the Toledo gauge go back to 1941; records based upon hourly scaled values go further back.

From the Lake Survey records we have obtained for the years 1941-1967 inclusive each year's maximum and minimum instantaneous stand of water level at Toledo, expressed as feet above or below the monthly mean lake level at Toledo for the month in which the maximum or minimum occurred. For the 27 years available these maxima and minima of water-stand have been categorized by 1-foot intervals and reduced to recurrence intervals in years per case. The results are as follows:

Table 2. Toledo annual maximum instantaneous levels above monthly mean.

Categories	1 foot	2 feet	3 feet	4 feet	5 feet
Cases	3	10	11	2	1
Cases ≥	27	24	14	3	1
Recurrence Interval, years per case	1.00	1.125	1.925	9.00	27.00

Table 3. Toledo annual minimum instantaneous levels below monthly mean.

Categories	3 feet	4 feet	5 feet	6 feet	7 feet
Cases	5	9	8	4	1
Cases ≥	27	22	13	5	1
Recurrence Interval, years per case	1.00	1.23	2.08	5.40	27.00

Each of these sets of data was plotted on a semilog graph and a least squares regression line computed for it, each regression line being extended to the 100-year recurrence interval. The results are shown in Figure 4.

The regression lines show that a maximum short-term water level rise of 7 feet may be expected at Toledo once in 100 years, and that a maximum fall of water level of 9.3 feet may be expected at Toledo once per century.

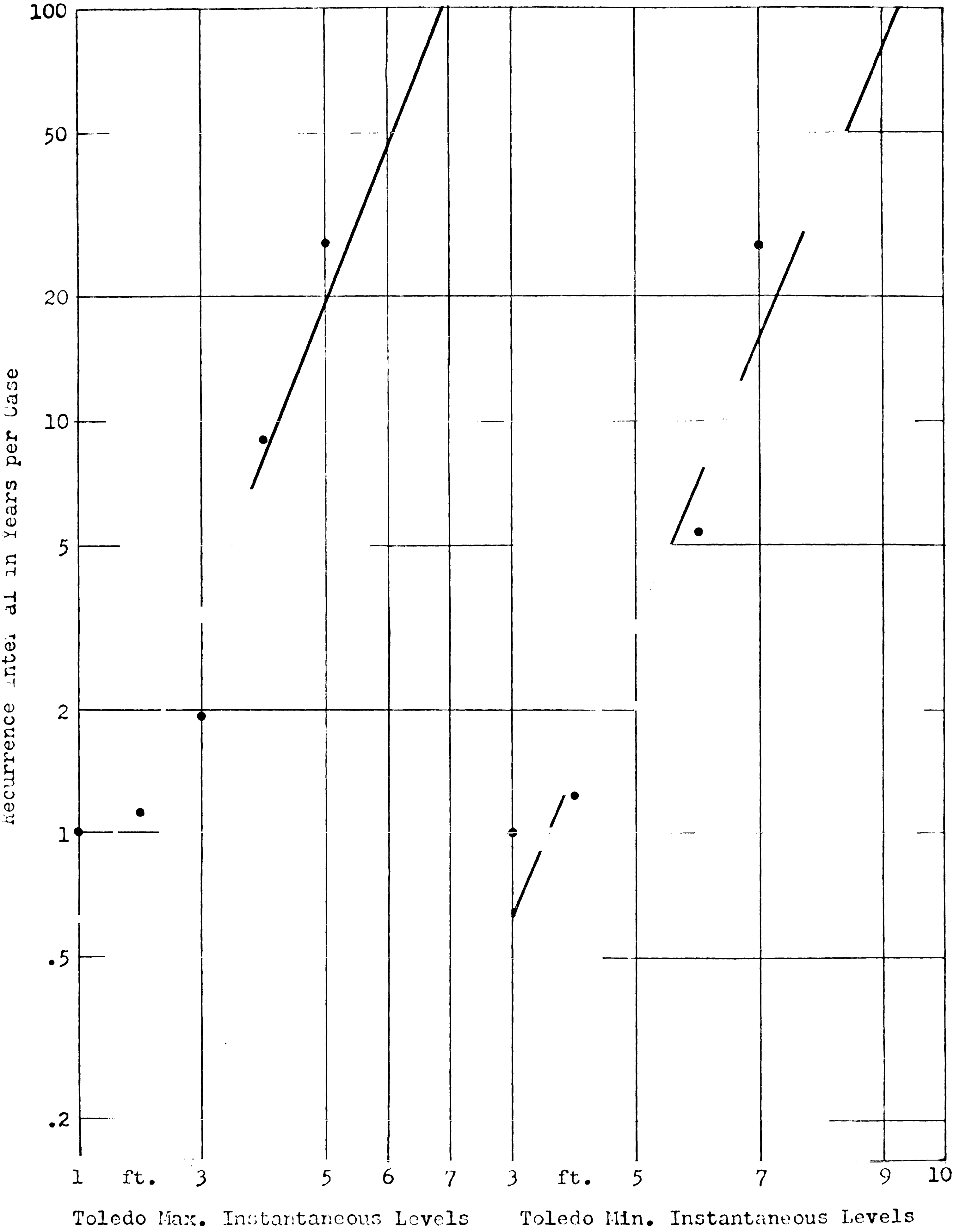
As an additional estimate of the maximum storm tide drawdown of water level at Toledo, recourse was had to the data on 76 wind tides in the 20 years 1940-59 inclusive which were studied by Irish and Platzman. These data were hourly data and were kindly loaned by Dr. Platzman. For each of these storms the minimum hourly water level (maximum drawdown) at Toledo was determined and expressed in feet below the Toledo monthly mean water level of that month. From the 76 storms there were 75 in which the fall of water level at Toledo equalled or exceeded 2 feet. The results are given in the following table:

Table 4. Toledo drawdowns, Irish-Platzman wind tides.

Categories	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet
Cases	15	35	13	7	3	2
Cases ≧	75	60	25	12	5	2
Recurrence Interval, years per case	0.267	0.333	0.800	1.67	4.00	10.0

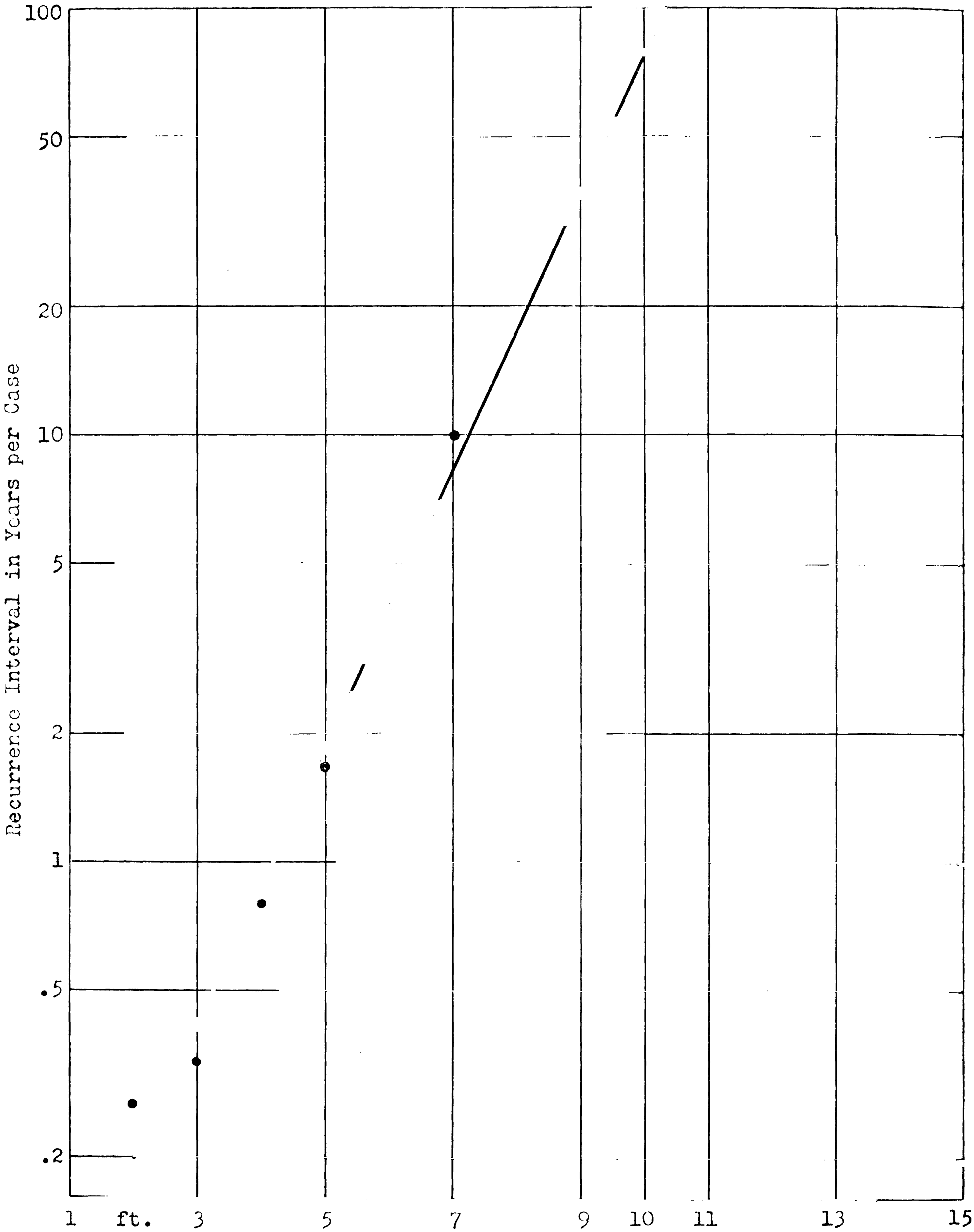
These data were plotted on a semilog graph and a least squares regression line computed; the regression line was extended out to the 100 year recurrence interval. This graph is shown in Figure 5.

This graph differs from the graph of minimum instantaneous levels only in that it indicates a once-per-century drawdown of 10.3 feet as opposed to



100
50
20
10
5
2
1
.5
.2
Recurrence Inter al in Years per Case
1
ft.
3
5
6
7
3
ft.
5
7
9
10
Toledo Max. Instantaneous Levels
Toledo Min. Instantaneous Levels

Figure 4



Toledo Water-Level Drops, Platzman's 75 Storms.

Figure 5

9.3 feet. Having no reason to prefer either of these estimates of the probable minimum water level at Toledo, we have accepted the average of the two, 9.8 feet.

Some, but not all, of the roughly cyclical variations in Lake Erie water level could be additative to the maxima and minima at Toledo.

The main uninodal lengthwise seiche of Lake Erie might, when a major storm occurs before the seiche from a previous storm has subsided, provide some increment of wind-tide water-level rise or fall at Toledo but that increment would be included in the observed water level changes. The maximum amplitude of the lengthwise uninodal seiche cannot occur until the storm has lessened or passed, and the setup at one end of the lake or the other has been freed to oscillate. We consider it physically impossible for a maximum wind setup or drawdown at Toledo during a storm to coincide with the maximum amplitude of the uninodal main lengthwise seiche because that maximum amplitude must occur after the storm.

The once-in-100-years 7-foot rise at Toledo might occur at the top of a 4.2-foot long-term high lake level. It could, further, occur at the top of the 2.75-foot maximum annual rise of record, and it might also occur under such conditions that the transverse seiche of the western basin was adding 1 foot of elevation. The total of this combination is 14.95 feet above datum at Toledo.

The once-per-century 9.8-foot drop of water level at Toledo might occur at the bottom of the 1.2-foot low-lake stage of record. It might, also, occur at the bottom of a 2.75-foot maximum annual variation in level. And it might occur at a time when the transverse seiche of the western basin had removed 1 foot of water level. The total of this particular combination is 14.75 feet below datum at Toledo.

The Locust Point plant is, however, not to be at Toledo which is in narrowed and constricted Maumee Bay at the extreme western end of the lake. Outside of Maumee Bay the cross-section of the lake increases rapidly, and water-level changes which have to be referred to the Toledo gauge may be expected to diminish accordingly.

Apparently only Hunt (1959) has given consideration to the stand of lake level along the lake axis during the major wind tides. Two figures from Hunt for setup levels in the WSW storm of 8 November 1957 are given in Figure 6.

The upper of these figures indicates that Locust Point is located at about 0.8 of the straight-line distance from the nodal point of the wind-tide setup to Toledo. The lower of Hunt's figures indicates that at 0.8 of the distance from the nodal point to Toledo the fall of water level would be at least 2 feet less severe than that at Toledo.

Deducting 2 feet from the 14.75 feet of worst-case drawdown at Toledo leaves minus 12.75 feet, and indicates that the 10-foot-deep intake channel at Locust Point might, about once per century, be dewatered by a combination of wind tide on top of long-term and annual lake level variations topped by the short-term transverse seiche of the western basin of the lake.

If materials now in our hands are correct, the plant is to be protected against flooding to 582 feet (13.4 feet above lake datum). If, as Hunt implies, the relationship of lake proportions and depths to setup at Toledo under ENE winds is the same as for setup at Buffalo under WSW winds, then it is appropriate to subtract 2 feet from Toledo's probable maximum setup of 14.95 feet in order to approximate the condition at Locust Point.

Under these conditions it appears that the plant's 13.4 feet of protection against flooding is adequate.

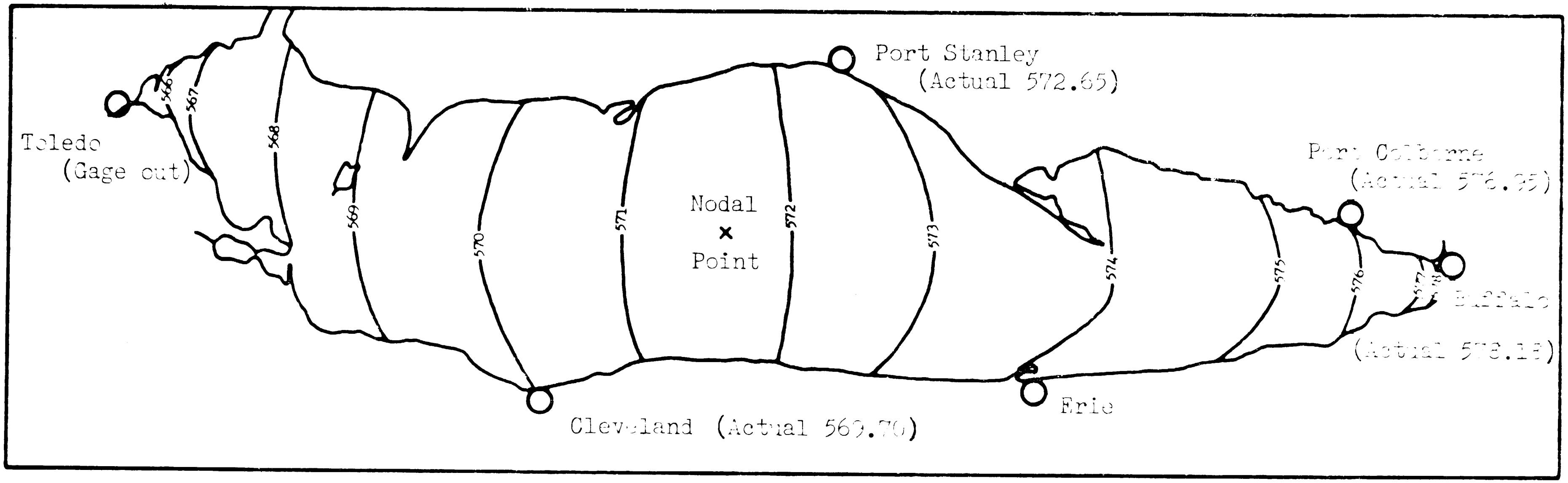


Fig. 10. Contours of computed water levels for 2200 hours, 8 November 1957.

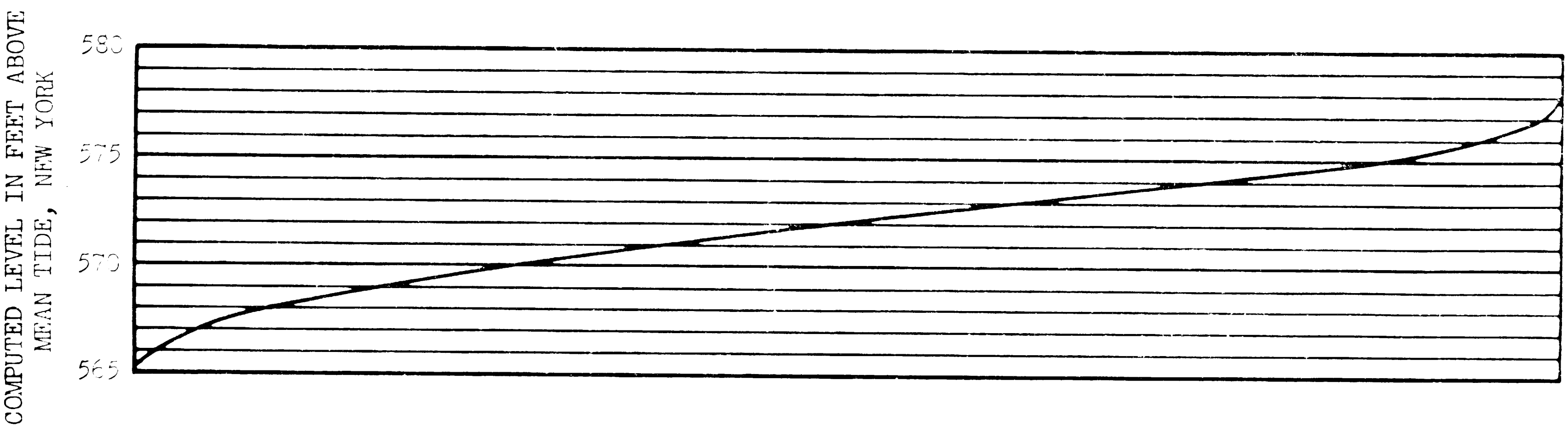


Fig. 11. Profile of computed water levels for 2200 hours, 8 November 1957.

Figure 6 (from Hunt 1959)

THE MAXIMUM WIND-WAVE

Wind-generated waves are limited in their dimensions by wind velocity, by fetch (open-water distance available for wind action), and by duration of the wind. Higher wind velocities, longer fetches, and longer wind durations all increase the heights, lengths, and velocities of the waves.

Neither wind velocity nor duration of wind are subject to control by the lake basin, but fetch is a physical characteristic of the lake basin. At Locust Point the available fetch plays an important part in the question of the height of the maximum wave that might arrive at the plant, on top of the maximum high water from other causes.

The once-per-century high water that could occur at Locust Point is predominantly the result of wind setup under prolonged strong wind from the ENE. Locust Point is in the western basin of Lake Erie, and wind-waves generated by ENE winds over the rest of the lake find their access to the western basin almost completely blocked by the islands that separate the western basin from the central basin. Those parts of waves from the eastern parts of the lake that succeed in passing through the islands are damped, refracted, and reflected into a confused sea around the western sides of the islands. From here the ENE wind must construct the maximum wave that will bear upon Locust Point. Toward eastnortheast from Locust Point the maximum fetch is 12.5 statute miles, or 20.1 kilometers.

Among the four expressions commonly employed in computation of the maximum wind-wave, that of Stevenson (1852) consistently gives the highest computed "highest waves under the strongest winds". Stevenson's empirical formula is:

$$H = 1/3 \sqrt{F}$$

where H is in meters and F (fetch) is in kilometers. Though the Stevenson equation is empirical and old, it has not been disproven. Defant (1961,Vol. 2,p.95)

says of it: "The formula was established by means of data from lakes, where the value of [fetch] ranged from a few kilometres up to 250 km. For the Mediterranean Cornish has verified the relation for fetches up to 830 km, and it is generally assumed that the realtionship holds for values of [fetch] up to 1000 km." Hutchinson (1957, p. 356) says of the Stevenson equation: "For Lake Superior, with a fetch of 482 km., the formula gives 7.3 m. as the height of the highest waves, in good agreement with the 6.9 m. reliably recorded."

Since the Stevenson relation was evolved on lakes, since it has apparently performed well in Lake Superior, and since it gives the greatest predicted wave height, it has been accepted in this case.

Substituting in the equation:

$$H_m = 1/3 \sqrt{20.1 \text{ km}}$$

H = 1.49m or 4.9 ft as the highest wave possible in the fetch available between the islands and Locust Point under ENE winds.

Taking the ratio of wave height to wave length to be 1:10 instead of the theoretical maximum 1:7, we have the wave length of the 4.9 foot wave as 49 feet. Sverdrup <u>et al</u>. (second printing, 1946, pp. 536-537) say: "Short wind waves are nearly unstable in deep water and they therefore break shortly after they have felt bottom....". 'Feeling bottom' consists of the local depth of water becoming less than half the wave length, therefore the Locust Point maximum wave of 49 feet wave length should break in something like 24 feet of water depth. If this wave comes in on top of the 12.95 foot maximum water level from all other causes, it should break in about 11 feet of charted water depth. Eleven feet of charted depth occurs at 2100 feet from shore at a total distance of 6,900 feet from the plant. In this distance another, smaller, maximum wave would form. Applying Stevenson's formula again gives 0.48 m or 1.6 feet for the height of this wave. Its wave length, computed as before, would be 16 feet and its half wave-length 8 feet.

Waves approaching the plant from the ENE during a high water of 12.95 feet would enter the plant property between the diked intake and outflow channels. The dikes of both these channels are to be 12 feet high above lake datum and would thus be covered by 0.95 ft of water. The lakeward dikes of the two channels would thus trip all but very small waves and cause them to break into the channels. The landward two dikes of the two channels would offer additional wave-breaking capacity if it was needed.

By the time the second wave has been broken directly in front of the plant, no fetch remains for additional waves to develop.

We foresee three additional factors that will tend to reduce the possibility of flooding from the maximum wave. It is our understanding that material excavated from the intake and outflow channels will be placed on the backbeach of the present shore; this artificial increase of existing land levels will be beneficial in tripping waves that come ashore during extreme high water. Many trees and shrubs of more than 13 feet height exist in the marshes behind the beach; these will be left in place and should have some disruptive effect on waves coming inshore during extreme high water. The sides of the dikes along the two channels will be sloped much more steeply than normal underwater topography. Waves coming inshore during extreme high water will encounter the steep dike sides too abruptly to permit the center of the waves crests to outrun the edges; the harbor-surging type of phenomenon is not expected.

Runup of the Maximum Wave

In our opinion the physical conditions described above preclude runup of the maximum wave as a producer of flooding at the plant.

THE PROBABILITY OF TORNADO DAMAGE

From studies of tornado frequencies and of tornado path width and length in Iowa and Kansas during the period 1953-62, H.C.S. Thom of the Office of Climatology of the U.S. Weather Bureau devised (Thom 1963) a means of predicting the probability and recurrence interval of a tornado striking a point in any 1° latitude-longitude square in the eastern three quarters of the United States.

Basically the method consists of determining the mean length and width of tornado paths from 230 tornados, obtaining the mean area of a tornado path, ascertaining the mean annual frequency of tornados in each 1° square, multiplying mean path area by mean annual frequency, and dividing by the area of the 1° square involved.

Thom's mean tornado path area is 2.8209 miles^2. His Figure 4 gives a mean annual tornado frequency of 0.8 for the 1° square centered at 41°30', within which the Locust Point plant would be located. The areas of 1° squares diminish with increasing latitude, from Thom's Table 4 of areas of 1° squares we have the area of the square centered on 40°30' latitude as being 3634 mi^2, while the area of the square centered on 45°30' is 3354 mi^2. By linear interpolation the area of the square centered at 41°30' is 3578 mi^2.

Substituting into Thom's equation:

$$\text{Probability} = \frac{2.8209 \text{ mi}^2 \text{ mean path} \times 0.8 \text{ tornados per year}}{3578 \text{ mi}^2 \text{ area of square}}$$

$$= \frac{2.2567 \text{ mi}^2 \text{ in square swept by tornados/year}}{3578 \text{ mi}^2 \text{ area of square}}$$

$$= 0.00063$$

Recurrence interval = 1/Probability = 1/.00063 = 1587 years

By this method it appears that any given point in the square centered on 41°30' might be swept by a tornado once in somewhat over 1500 years.

SIZE AND STRUCTURE OF THE THERMAL PLUME

Warmed condenser-cooling water will be discharged from the Locust Point plant to Lake Erie where it will form a floating plume that varies in its dimensions and direction as environmental conditions change. Plume dimensions diminish as the temperature difference between plume water and ambient air becomes larger. Plume dimensions diminish as evaporation, ventilation, and wave action are increased by higher winds. Plume direction shifts under the influence of local winds and water currents. Plume shape tends to be fan-like under calm winds, and to become horse-tail-like under the action of wind and current.

At Locust Point calm winds are rare and of short duration, under these conditions residual current from the preceding wind usually will produce the horse-tail shape of plume.

Maximum area of the plume is to be expected under light winds blowing from the land to the lake, which keep the plume out of the wave action of the surf zone along the beach. Maximum plume area occurs under winds so light as to produce no significant wave action in the open water. All other things being equal, the greatest area of plume occurs in the height of summer when the difference between plume temperature and air temperature is least.

The maximum length and breadth of the plume determine whether plume water can reach any sensitive point in the local region. It is pertinent, therefore, to assess the probable maxima of these dimensions.

Studies of several existing thermal plumes have been drawn upon in this section. The Waukegan, Illinois, generating station of Commonwealth Edison Company is situated on the upwind shore of Lake Michigan and under the prevailing wind feeds a fairly symmetrical plume into the open lake. This condition is identical to that at Locust Point. From the report of Beer and

Pipes (1969) the length:width proportions of the Waukegan plume were determined and modified to produce a symmetrical plume. These modified proportions were then applied to the expected plume at Locust Point. The Waukegan report is given in Appendix B.

In the west end of Lake Erie south of Monroe, Michigan, the Consumers Power Company operates its J. R. Whiting generating plant. Consumers has granted us permission to use data from a number of surveys which they made in the plume of the Whiting plant in the summer of 1967. The data used form Appendix C.

The Michigan Water Resources Commission has granted us permission to use a temperature survey made by them in the plume of the Traverse City, Michigan, Municipal Power Plant. This survey is Appendix D.

Appendix E is a survey made by us in the plume of the Consumers Power Company Big Rock Nuclear Plant near Charlevoix, Michigan.

The uses made of these data are indicated in subsequent parts of this section.

Three summer 1967 surveys at the Whiting plant, made under the prevailing southwest wind, were used as the basic materials for the estimation of length of the Locust Point plume. Although these surveys did not capture the entire length of the plume, as was done at Waukegan, they were adjudged to have more relevance to Locust Point than Waukegan has. All three plants are on upwind shores relative to prevailing winds, but the bottom at Waukegan is relatively steep-to, while Whiting and Locust Point are located on very gently sloping bottoms covered by shallow water. For this reason the behavior of the Whiting plume was deemed more indicative of that at Locust Point.

The three summer SW wind surveys at Whiting (29 June, 20 July, and 3 August 1967) showed in their surface temperatures at 3000 ft from the discharge channel mouth a mean loss of 80% of the 14°F delta-T being added by the plant.

Proportioning:

$$80\% : 3000 \text{ ft} :: 100\% : x$$

$$x :: 3750 \text{ ft}$$

The proportioning technique was checked on the Waukegan plume; it over-estimates the length of plume by a few percent and is considered both acceptable and conservative.

Taking 3750 ft as the maximum length of the Whiting plume under light SW winds in the height of summer, and multiplying by factors for plant-size and delta-T difference it is possible to estimate the probable length of the Locust Point plume under similar summer conditions. The computation used was:

$$\text{Whiting plume} \times \frac{\text{Locust outflow}}{\text{Whiting outflow}} \times \frac{\text{Whiting delta-T}}{\text{Locust Pt. delta-T}}$$

$$3750 \text{ ft} \times \frac{\text{Locust outflow}}{214{,}000 \text{ gpm}} \times \frac{14\%}{\text{Locust Pt. delta-T}}$$

It is to be noted at this point that the last factor is the inverse of the way that such fractions have been used before. This results from Kolflat's (1968) report that cooling waters discharged at higher temperature cool more rapidly than do those discharged at lower temperatures. It is also consistent with two precepts of basic physics: warmer water is less dense and floats better on cooler ambient water; and rate of cooling is proportional to the gradient of temperature from heat source (plume water) to heat sink (ambient air).

The computations made for the Locust Point plume included probable maximum lengths and breadths of plume at three different delta-T levels, at different rates of cooling-water discharge, and with one or two units in operation. The results are presented in the following table. Maximum plume width was taken to be 58% of plume length, as determined from the symmetrical plume developed for Waukegan (discussed later).

Table 5. Maximum Lengths and Widths of Locust Point Plume Under Different Operating Conditions.

Units in Operation	Cooling-Water Discharge	Delta-T	Maximum Length	Maximum Width
1	1,200,000 gpm	10°F	5.5 miles	3.2 miles
1	800,000	15°	2.4	1.4
1	600,000	20°	1.4	0.8
2	2,500,000	10°	11.6	6.7
2	1,600,000	15°	5.0	2.9
2	1,200,000	20°	2.8	1.6

From the plumes that have been studied it is now possible to obtain some information about the internal thermal structure of plumes. Present data have their greatest strength in showing the decay of delta-T along the lengthwise axis of the plume. Less definitive data as to the lateral distribution of thermal structure in the plume have been obtained from the Waukegan plume.

In plumes where the data are presented in "three dimensional" form as at Whiting and Traverse City it is possible to pick out stations along the axis of the plume and to work directly from the tabulated data; in plumes like Waukegan and Big Rock it was necessary to contour the field of surface temperature, and to work from contour-line values along the axis of the plume. In both cases the sought values were (discharge-channel delta-T minus observed surface temperature) over (discharge-channel delta-T), giving percent loss of delta-T at positions along the axis of the plume. The resulting data are in the form of percent of loss of delta-T at percent of plume length. The results of these determinations are presented in Figure 7, wherein actual data points are marked by symbols and connected by straight-line segments. A visual curve of best fit is drawn without symbols through the field of data curves.

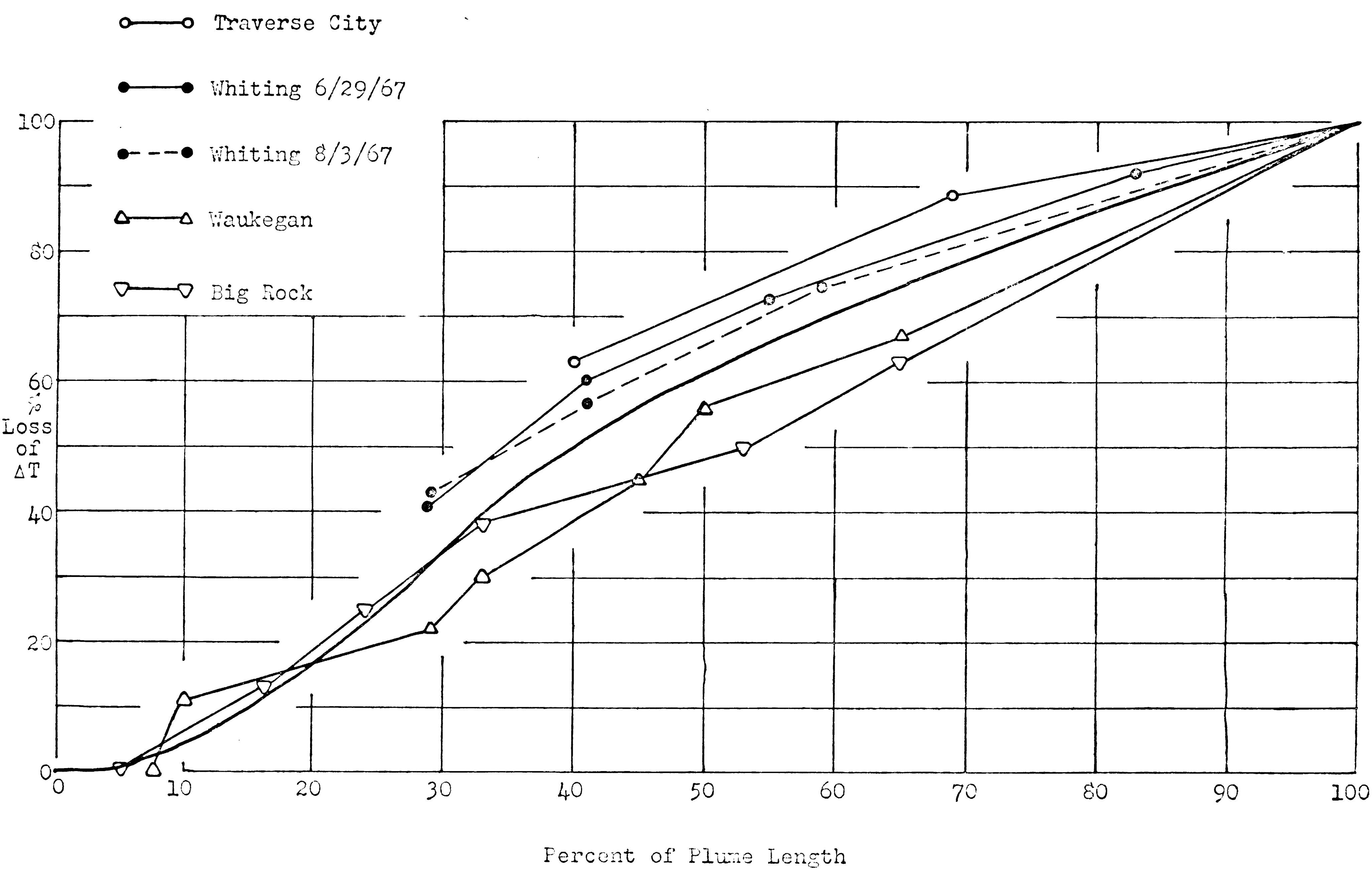

Traverse City
Whiting 6/29/67
Whiting 8/3/67
Waukegan
Big Rock
% Loss of ΔT
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
100
Percent of Plume Length

Figure 7

From the results obtainable to date, it appears that the most rapid loss of delta-T occurs between 10% and 50% of the plume length. Tabulated readings from the best-fit curve are:

Table 6. Decay of Delta-T in Surface Temperature Along Plume Axis.

Percent Loss of Delta-T	Percent of Plume Length
0	3.0
1	5.0
10	15.5
20	22.3
30	28.0
40	33.0
50	40.0
60	48.5
70	59.0
80	72.0
90	85.5
100	100

In regard to the lateral distribution of plume width along the length of the plume, Waukegan's partly symmetrical plume offers the best data available to date. A straight axial line was drawn through Figure 1 of Beer and Pipes' report from the center of the mouth of the discharge flume to the most lakeward point of the observed plume. From this axial line the northward distance to the lateral edge of the plume was approximated by the distance scale of their figure. These northward half-widths were doubled to provide a symmetrical plume. The relations resulting are given in the following table:

Table 7. Length-Width Relations in a Symmetrical Plume at Waukegan. Origin at center of discharge-flume mouth.

Distance from Origin, feet	Full Width, feet	Distance from Origin as % of Plume Length	Full Width as % of Length
0	190	0	Flume Width
200	600	7	21%
400	820	14	28
600	900	21	31
800	960	28	33
1000	1080	35	37
1200	1280	41	44
1400	1500	48	52
1600	1580	55	55
1800	1660	62	57
2000	1680	69	58
2200	1420	76	49
2400	1280	83	44
2600	880	90	30
2800	520	97	18
2900	0	100	0

Since Waukegan and Locust Point are both on the upwind shore under prevailing winds, and the prevailing wind in both cases blows from shore to open lake, both plants ideally should feed symmetrical plumes into the open lakes.

From the scanty temperature data given in Beer and Pipes' Figure 1 the internal distribution of loss of delta-T at 1 foot depth was obtained and adjusted to conform to the surface distribution along the length axis that was determined from much more data in Figure 7 above. The results are best presented descriptively:

Isoline of 0% loss of delta-T:

Occupies 50% of discharge flume mouth, 25% on each side of center, and reaches the plume length axis at 3% of the plume length.

Isolines of 10% through 60% loss of delta-T:

Occupy respectively 51%, 52%, 53%, 54%, 55%, and 56% of the discharge flume mouth; all percentages divided half-and-half on both sides of the flume-mouth centerline. These isolines extend lakeward to reach the plume-length axis at 15.5%, 22,3%, 28.0%, 33.0%, 40.0%, and 48.5% of plume length, respectively.

Isoline of 70% loss of delta-T:

Originates occupying 60% of outfall mouth width (30% each side of center) and extends lakeward to reach plume length axis at 59.0% of plume length.

Isoline of 80% loss of delta-T:

Originates occupying 67% of outfall mouth width, equally divided by centerline, and reaches length axis at 72.0% of plume length.

Isoline of 90% loss of delta-T:

Originates at 80% of outfall mouth (40% on each side of center) and reaches length axis at 85.5% of plume length.

Isoline of 100% loss of delta-T:

Originates at 100% of outfall mouth width, follows length-width relations of a symmetrical plume given in Table 7, and reaches the length axis at 100% of plume length.

Given the length-width relations of the outer boundary, the origins in the outfall mouth and the axial-points, two experienced persons will draw very similar contours of the internal distribution of loss-of-delta-T. With this much to work from, our concept of the surface nature of the Locust Point plume is presented in Figure 8. This figure is generalized; it is intended that suitable numbers for plume length will be incorporated from Table 5, and that the Locust Point outfall mouth width of 250 feet will be used.

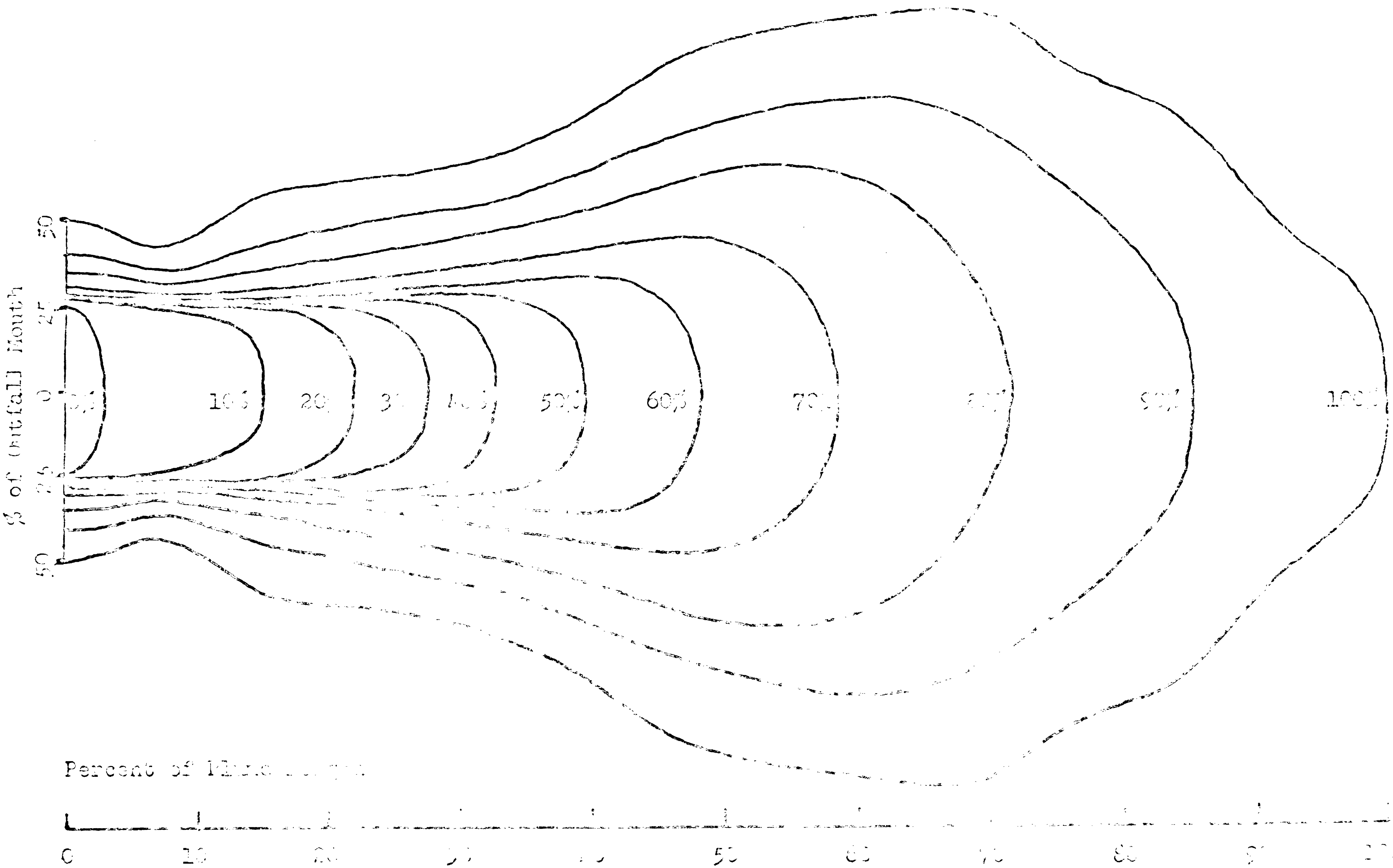


Figure 8

In the matter of the distance from the outfall channel mouth to which the outflow current may be expected to produce bottom scour, we have worked from the behavior of the plume at the Whiting plant in the shallow water of western Lake Erie under light west wind on 7 September 1967 when the plume best crossed the grid of sampling stations. On this day the plume, with a 14.4° delta-T, was on bottom (scouring) in 5 feet of water at 1500 feet from the discharge channel mouth while at 5 feet of depth at 2000 feet from the channel mouth it was floating off the bottom. We have taken 1750 feet as the radius of bottom-scour around the Whiting discharge channel mouth, this is 22% of the plume length estimated for this west-wind day; the 5-foot depth to which the plume reached bottom is 0.06% of the plume length.

Applying these percentages to the lengths of Locust Point plumes estimated in Table 5 gives:

Table 8. Depths and Lengths of Scouring Under Different Operating Conditions.

	One Unit			Two Units		
	10°ΔT	15°ΔT	20°ΔT	10°ΔT	15°ΔT	20°ΔT
Depth at .06% of plume length, feet	17.5	7.6	4.4	36.9	15.7	8.8
Scour radius, 22% of plume length, feet	4235	2805	1617	13503	5775	3217

We believe that the bottom topography off the outfall channel mouth will be modified by current scour to reduce the larger of these estimates. For 325 feet out from the channel mouth the bottom is of sand bars and a sand flat with less than a foot of water over them at lake datum. From 2 feet of depth at 800 feet from shore to 8 feet of depth at 1320 feet out the bottom slopes at about 1 foot per 100 ft. Sand from the flat and bars will be scoured by the outflow current out into the zone of 1% slope where it will make a submerged

deltaic fan with lakeward slopes steeper than 1%. We anticipate that the outflow current will take off in ski-jump fashion from the deltaic fan and become floating at that point, which we cannot more sharply determine at present.

It is possible to derive an internal vertical distribution of loss of delta-T for an idealized or static plume; to do so, however, is meaningless because the bottoms of plumes show bulges downward and constrictions upward (see both Waukegan and Big Rock in the Appendices), possibly as the result of internal waves or of the sizes of local turbulence eddies. The internal distributions of temperature within the plume bulge downward and constrict upward in phase with, but in smaller proportions than, the variations of the plume bottom.

It is probable that, in any short period of constant plant operation, there is a constant volume of water in the plume. Travelling, but repeated, vertical anomalies of thickness of plume may account for the fact that simple straight-line scaling accounts better for the observed length of plume at Waukegan than does classic exponential die-away.

References

BEER, L. and W. O. PIPES. 1969. No Notable Change in Lake Due to Station Discharge. Electrical World, Feb. 10, 1969. pp. 24-26.

DEFANT, A. 1961. Physical Oceanography. Pergamon Press, New York, N.Y. 2 vols., 729 pp. and 590 pp.

HARTLEY, R. P. 1964. Effects of Large Structures on the Ohio Shore of Lake Erie. Division of Geological Survey, Department of Natural Resources, State of Ohio, Columbus, Ohio, Report of Investigations No. 53. iv and 30 pp., 34 figures.

HARTLEY, R. P., C. E. HERDENDORF, and M. KELLER. 1966. Synoptic Water Sampling Survey in the Western Basin of Lake Erie. pp. 301-322 in Proc. 9th Conf. Great Lakes Research, Univ. of Michigan, Ann Arbor, Mich.

HERDENDORF, C. E. (compiler). 1967. Lake Erie Bathythermograph Recordings 1952-1966. Information Circular No. 34, Ohio Department of Natural Resources, Division of Geological Survey, Columbus, Ohio. iii and 36 pp., 2 figs., many tables.

HUNT, I. A. 1959. Winds, Wind Set-Ups and Seiches on Lake Erie. Research Report No. 1-2. U.S. Corps of Engineers, U.S. Lake Survey. Detroit, Mich. 59 pp., 23 figs., 6 tables.

HUTCHINSON, G. E. 1957. A Treatise on Limnology. Vol. 1. Geography, Physics, and Chemistry. John Wiley and Sons, Inc., New York, N.Y. 1015 pp.

IRISH, S. M. and G. W. PLATZMAN. 1962. An Investigation of the Meteorological Conditions Associated with Extreme Wind Tides on Lake Erie. Monthly Weather Review, 90, 39-47.

KOLFLAT, T. O. 1968. Cooling-Water Debate Needs Clarification. Electrical World, August 19, 1968.

OLSON, F. C. W. 1951. The Currents of Western Lake Erie. Doctoral Thesis, Ohio State University, Columbus, Ohio.

PLATZMAN, G. W. 1966. The Daily Variation of Water Level on Lake Erie. Jour. Geophys. Res., 71(10): 2471-2483.

RODGERS, G. K. (compiler). 1962. Lake Erie Data Report 1961. Preliminary Report Series - No. 3, Great Lakes Institute, Univ. of Toronto, Toronto, Ontario. iii and 141 pp., 14 figs., many tables.

STATE OF OHIO. 1957. Bottom Deposits of Western Lake Erie. 4 pp. and one chart. Division of Shore Erosion, Department of Natural Resources, State of Ohio, Columbus, Ohio. Technical Report Number 4. April 1957.

STEVENSON, T. 1852. Observations on the relation between the height of waves and their distance from the windward shore. Edinbur. New (Jameson's) Philos. Jour., 53: 358-359.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1942. The Oceans Their Physics, Chemistry, and General Biology. Prentice-Hall, Inc., New York. 1087 pp.

THOM, H. C. S. 1963. Tornado Probabilities. Monthly Weather Review. October-December 1963, pp. 730-736.

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

LAKE ERIE SECTION
OHIO FISHERIES BUILDING
P. O. BOX 650
SANDUSKY, OHIO 44870

April 2, 1969

Dr. John Ayres
University of Michigan
Great Lakes Research Division
North University Building
Ann Arbor, Michigan

Dear Dr. Ayres:

I have been asked by our Division Chief, Mr. H.R. Collins, to answer your questions concerning the possible effects on littoral drift in the Locust Point area caused by the construction of an intake-outfall structure for the proposed power plant.

Our knowledge of actual current velocities and the volume of drift material actively involved in the littoral system in this area is limited. However, a study of the available current data and the present shoreline configurations clearly indicates a definite pattern of littoral characteristics.

The shoreline in the vicinity of Locust Point is within a nodal zone of predominant diverging currents and shows no appreciable drift in either direction. In the vicinity of Locust Point, the currents are, for all practical purposes, negligable.

The 15-mile stretch of shoreline between Locust Point and Little Cedar Point to the west is characterized by a predominant northwestward drift. This is due to the relatively long easterly fetch that extends to the Bass Islands area and the opposing short fetch of westerly winds. The littoral force produced by east and northeast winds reaches its maximum near the Little Cedar Point spit. The strength of the westerly movement diminishes eastward from Little Cedar Point. This stretch of shoreline produces very little beach-building material and has therefore become relatively static.

Eastward from Locust Point the direction of the dominant littoral current is southeastward and is relatively weak. The low

shore banks in this area, however, are composed of glacial till and produce larger amounts of beach-building material than is found west of Locust Point.

I can foresee no problems concerning excessive accretion of littoral material or starvation of down-drift shoreline areas due to the construction of an intake-outfall structure in the immediate vicinity of Locust Point. However, knowledge of the exact location and size of the structure would allow for a more accurate determination of the possible effects upon the adjacent shoreline.

I personally feel that the consideration of using a pumping station for the by-passing of sand is highly commendable and should be considered for use in all cases where potential down-drift areas may suffer starvation and consequent erosion due to the placement of large structures.

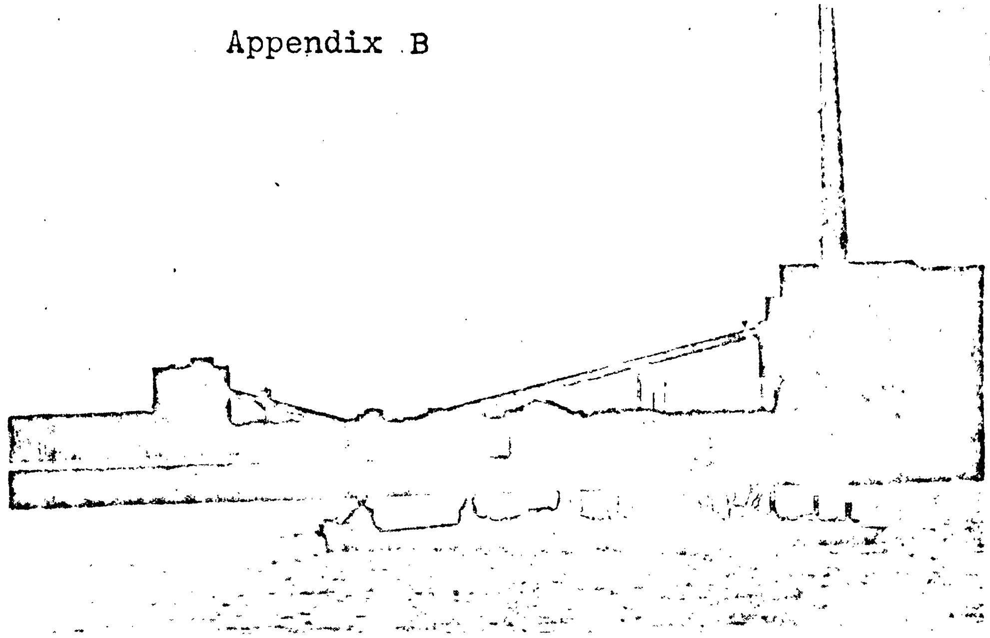
I hope that this letter answers any questions you may have had concerning the littoral system near Locust Point. If we can be of any further help to you, please feel free to call upon us at any time.

Sincerely yours,

Lawrence L. Braidech
Geologist

LLB/pm

cc: H.R. Collins



Dr L. P. Beer and Dr W. O. Pipes*

No notable change in lake due to station discharge

Temperature, chemistry, and ecology of littoral waters of Lake Michigan show no long-term effects in tests at 1,180-Mw Commonwealth Edison plant

No significant effect on the total near-shore environment along southwest Lake Michigan can be attributed to the discharge of cooling water from a large power station. This generalization is the conclusion of a team of scientists and engineers who studied the littoral environment and the influence of condenser outflow from the 1,180-Mw Waukegan Generating Station of Commonwealth Edison Co.

The study was made at the outfall of the station of temperature profiles in the lake, water chemistry, and indigenous organisms including plankton, benthos, attached algae, and fish. This station has a 40-year operating history and generated an average of 895 Mw during the month of observation. A similar study was made at the same time at the site of a proposed nuclear power plant four miles north of Waukegan Station near Zion, Ill. Similarities in aquatic environments were observed at both locations.

Specific conclusions are: Condenser water mixes with lake water in shallow depths near shore and floats on the surface of deeper cooler water. This mixing and stratification effectively dissipates the heat, so that no temperature difference can be detected 3,000 ft from shore. The extended period of higher temperatures has had only a slight effect on the chemistry of the water and has not significantly changed the dissolved oxygen concentration.

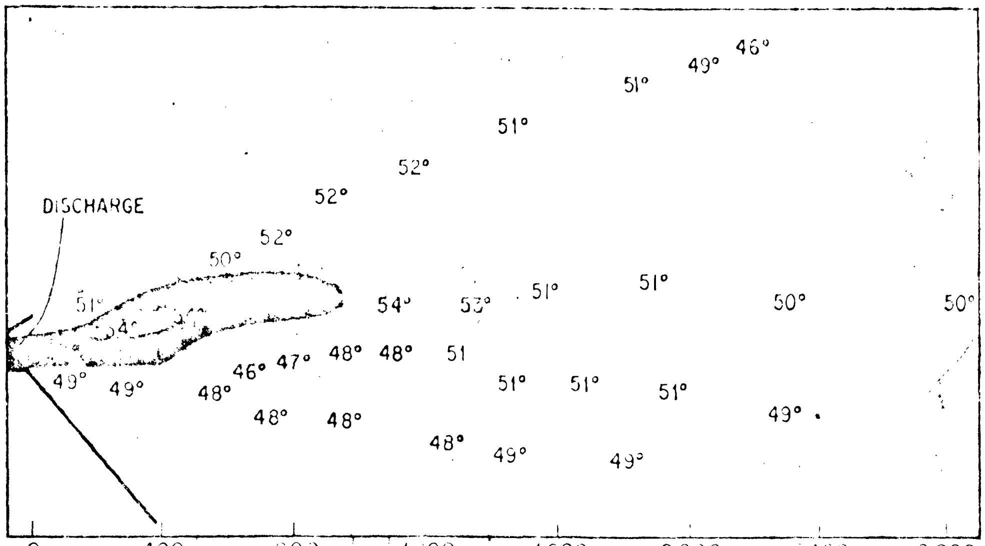
Benthic or bottom-living organisms vital to the food chain of commercial and sport fish have not been eliminated by discharge from the station. Plankton counts do not indicate any definite effect from the heated discharge. Sport fish, including trout and Coho salmon which frequent the water near the discharge, have not suffered any apparent deleterious effect.

Over-all purpose of the study was to gather practical data on the long-term effects of cooling water discharge in this part of Lake Michigan. The growing interest in cooling water which is discharged into bodies of water, is not matched by the amount of information available, much of which represents laboratory results and theoretical calculations of heat dissipation.

Another important goal of the study was development of a practical technique of observation for application to long-term studies. Although limited by the time and facilities available, this study demonstrates that it is possible to collect field data which can be used for direct evaluation of the long-term environmental effects of thermal discharges. From such data it is possible to extrapolate environmental effects nearby. Comparison of field data with theoretical eval-

* Dr L. P. Beer, Senior Staff Engineer, Environmental Studies, Commonwealth Edison Co, Chicago, Ill., and Dr W. O. Pipes, Professor of Civil Engineering, Northwestern University, Evanston, Ill.

←Water temperatures were collected at 1 ft intervals down to 30 ft depth at many locations within the station's discharge plume



Plume [Fig 1] of condenser discharge presented this horizontal isothermal map of Lake Michigan's surface

uation suggests the inadequacy of existing models to describe the complexity of nature.

It is generally accepted that the cumulative effect of multiple heat inputs from present and projected lakeside power stations on the over-all environment of Lake Michigan will be negligible. Combined heat inputs would raise the average water temperature less than 0.1F during one summer. This increase would be nullified during the following winter.

Because significant cumulative temperature change may be taken as non-existent, the study was confined to local effects of condenser water discharge. The outfall of Waukegan Station, about 40 miles north of Chicago along the southwest shore of Lake Michigan, was selected because it represents over 40 years of operation. Any possible deleterious effects of thermal discharges would surely be apparent. Zion was selected for control observations as it is the site of a nuclear power plant proposed by Commonwealth Edison.

Personnel in the study team had backgrounds in heat transfer [thermodynamics]; hydraulics; thermal, biological, and chemical instrumentation; ecology; and chemistry. Facilities included a 45-ft tug boat, a 20-ft barge and a 16-ft power boat. Instrumentation consisted of an L&N multi-channel recorder for water temperature measurements, a Peterson dredge for bottom sampling, a modified Kemmerer sampler for plankton, and equipment for analysis of the chemistry of lake water. Biologists of the Illinois Dept of Conservation provided data on fish collected with gill nets.

The field study was made during April, 1968. Observations were made while output of the power station was 895 Mw, giving a temperature rise through the condensers of 12F over average lake water temperature of 44F for a cooling water requirement of 760,000 gpm. During the study winds were light, generally less than 10 mph, varying from north-northwest to north-northeast. Ambient air was 55 to 60F and humidity 50 to 60%. Cooling water enters a 2,000-ft discharge flume with a 2.61 fps discharge velocity in the flume. At 3,000 ft offshore the water depth is 32 ft and the bottom slope averages 1%.

Water temperatures as a measure of heat dissipation in the cooling water outflow were taken with ten thermocouples at 1-ft intervals on a 10-ft probe on the end of a 20-ft hose. Temperatures measured to a 30-ft depth were recorded for direct readout on the multi-channel recorder. Observation points were located by triangulation from a shore base line. Depths were determined by sonar gear and direct sounding.

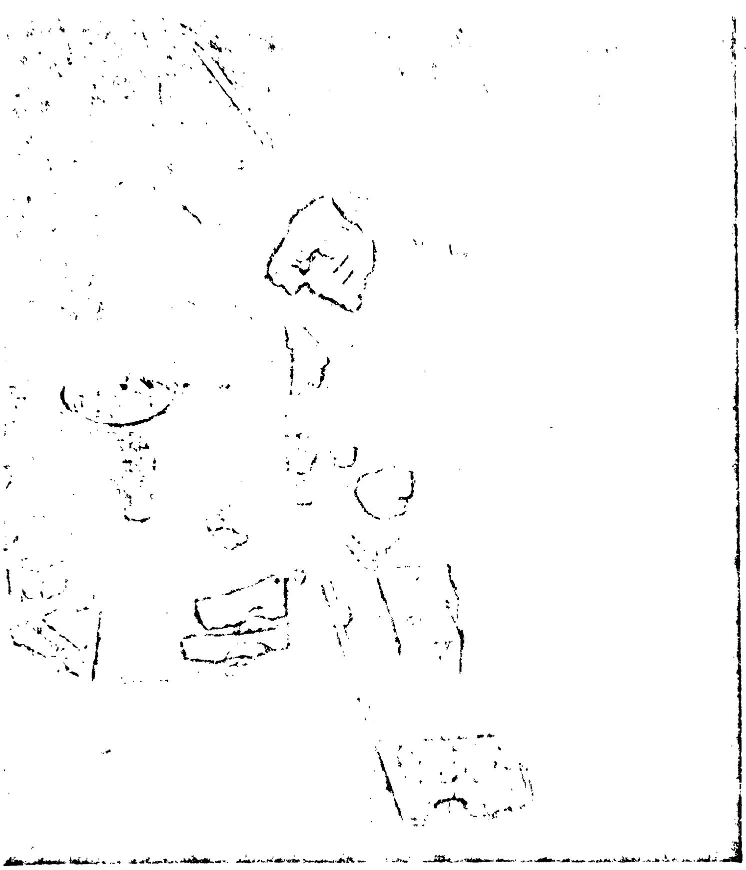
Indicative of heat dissipation rates in the plume are water temperatures at 1 ft below the surface. The plume had a maximum horizontal [east-west] length of 2,900 ft and a [north-south] width of 1,500 ft. Horizontal stratification occurred in the first 1,400 ft with temperatures of 5 to 9F above ambient in an irregular east-west band that was 150 to 200 ft wide. The plume was dominated [nearly 85%] in horizontal area by temperatures 2 to 4F above ambient.

With increasing depth the plume shortened and narrowed, and no water temperatures above ambient were found below 18 ft. Sedimentary buildup of the lake bottom is irregular with high spots, such that water depths greater than 18 ft are generally 1,500 ft from the shore. The character of the lake bottom is illustrated in Fig 2, which also shows a vertical isothermal cross-section of the plume.

Analysis of horizontal and vertical isothermal data reveals that the condenser discharge mixes rapidly with lake water and the increased temperature effect is moderated a short distance from the outfall. There is vertical stratification, with the temperature effect generally confined to the upper water. It is believed that better mixing can be effected through use of an outfall of improved design to moderate the effect of temperature.

From these measurements it can be concluded that heat dissipation is rapid in open water and is influenced by climatic conditions, bottom configuration and water movement. Increased wind activity, coupled with low humidity, tends to increase vertical heat dissipation. Bottom roughness or irregularity resulting from erosion and deposition causes increased vertical and horizontal mixing and enhances dissipation. Wind-induced currents either increase or retard heat loss.

Water samples from the plume and to either side of it were analyzed for chemical constituents using standard methods for the examination of water and waste water. Samples were analyzed for dissolved solids, al-



Survey crew made simultaneous observations of lake's thermal, chemical, and biological water conditions

kalinity, hardness, chlorides, sulfate, silica, calcium, magnesium, sodium and phosphate. At the three sampling locations the depth varied from 11 to 13 ft and the offshore distances from 400 to 1,200 ft.

Chemical variations between heated-water and ambient-water samples were negligible. Within the plume, however, ammonia concentrations were only 0.03 to 0.04 mg/l while they were from 0.06 to 0.12 mg/l in adjacent unheated zones. This suggests that the warmer water does not hold as much ammonia which is driven off into the air. There also were slightly reduced concentrations of nitrates and sodium in the effluent, but the difference over adjacent water was insignificant.

Dissolved oxygen, however, remained unchanged in the offshore area at near-saturation levels of 11.0 to 11.5 mg/l. This observation is reassuring in that dissolved oxygen is essential to fish populations.

Samples of bottom-living organisms were located offshore from both Waukegan and Zion. Methods of collection and examination followed standard approaches for examination of natural and waste water, with identification of species of organisms from standard references. The findings are indicative of the types and relative numbers of organisms present.

The same types of bottom organisms important in the food chain of commercial and sport fish were found at each location. Greater numbers of each type appeared to be present at Zion than at Waukegan, but there also was indication of larger amounts of organic matter in the lake bottom near Waukegan. This presence of more organic matter makes more difficult an estimation of the effect of the heated water.

Nonetheless, it appears obvious that bethnic organisms significant in the food chain are present in the littoral zone near Waukegan. It may be concluded that the discharge of cooling water has not reduced significantly these types of organisms.

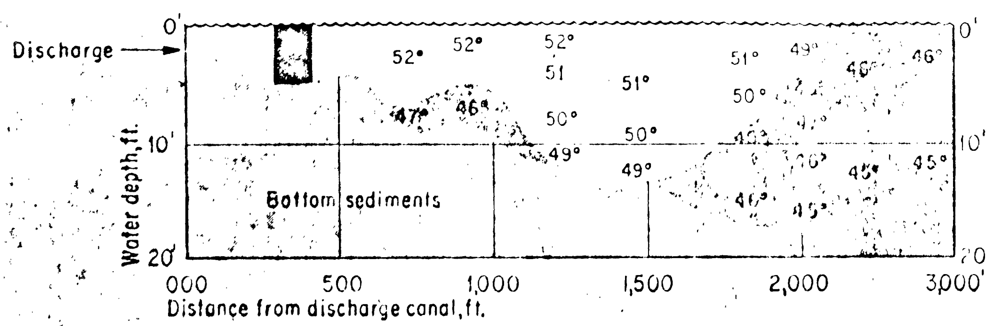
Water samples for plankton counts were collected, prepared for transportation, and examined in the laboratory. Each sample was examined by placing a 1-ml aliquot in a Sedgwick-Rafter counting cell. A survey count was made with a wide-field stereoscopic microscope and a strip count using a binocular compound microscope.

Plankton counts in samples taken at Zion were greater than in those from Waukegan. The variation could have been due to differences in wind-induced currents on the days of sampling. However, the results do not indicate any effect of the condenser discharge.

Observation was made of a filamentous green algae, common to the southwest shore of the lake, on the breakwater at Waukegan Station. While algae growths were present on the intake side, there was none along the side in contact with the cooling water discharge. Chlorine slug-fed into the cooling water on the intake side was rejected as the inhibiting factor. Of 12 attempts to identify chlorine residual in the plume, only one was successful—one at a concentration of only 0.25 ppm. This experience may support the conclusion that a local increase in water temperature has the beneficial effect of decreasing the growth of attached algae.

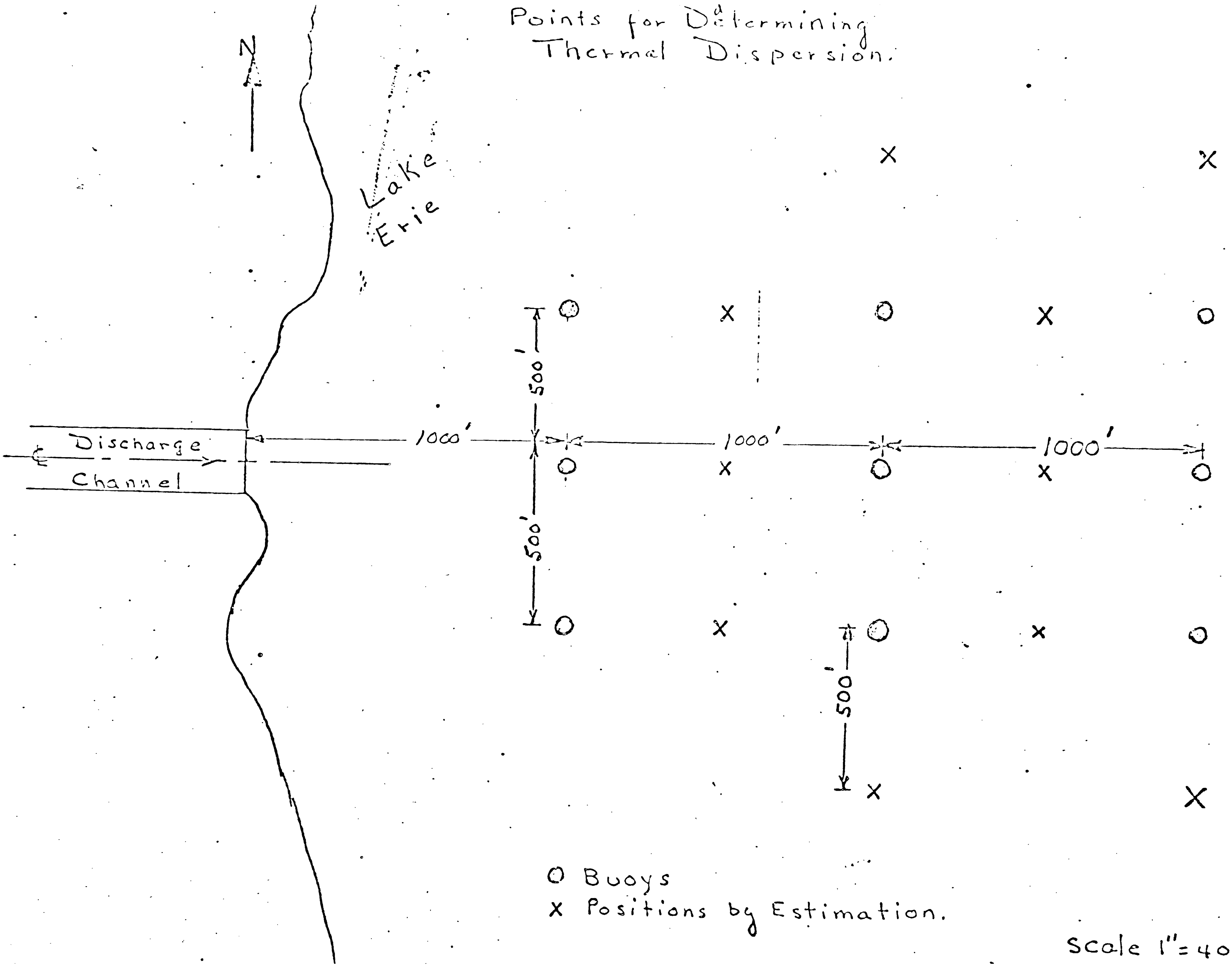
In two samplings of fish offshore from Waukegan, one sample 500 ft north of the discharge and 400 ft offshore included 32 Coho salmon, two rainbow trout, one large steelhead, and other species. According to the Illinois Dept of Conservation, the salmon catch was the highest made in a single net to date and "indicates a considerable abundance of salmon in this vicinity". In the other sample taken south of the breakwater and in an area not influenced by the heated effluent, within 300 ft of shore, only suckers and carp were collected.

Based on this sampling and a growing public interest in sport fishing, particularly Coho salmon, it may be concluded that the cooling water discharge at Waukegan has had no deleterious effect on fish environment.



Vertical isothermal cross section [Fig 2] follows the main 'stream' of the power station's effluent

Points for Determining Thermal Dispersion.

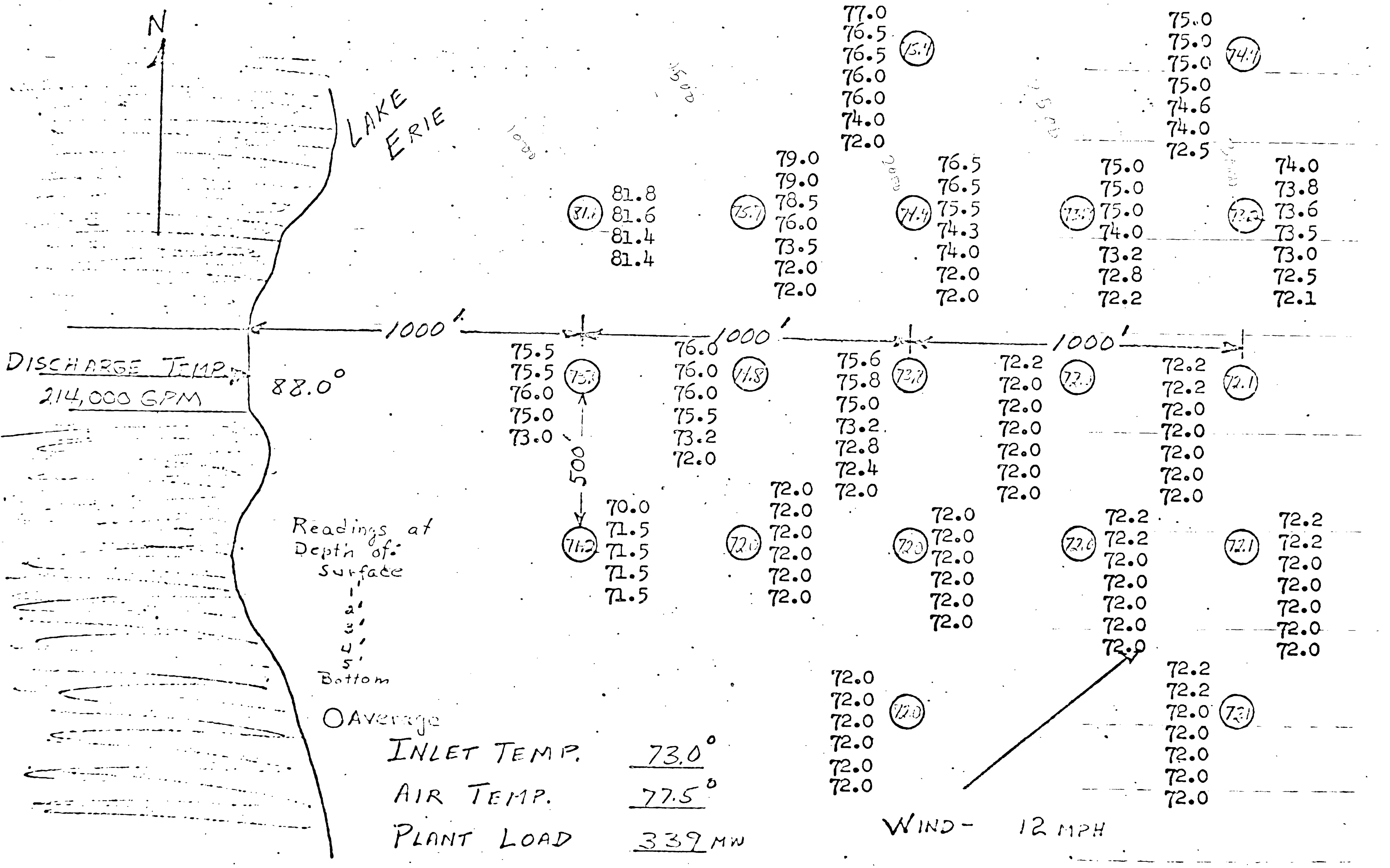


O Buoys
x Positions by Estimation.

Scale 1" = 400'

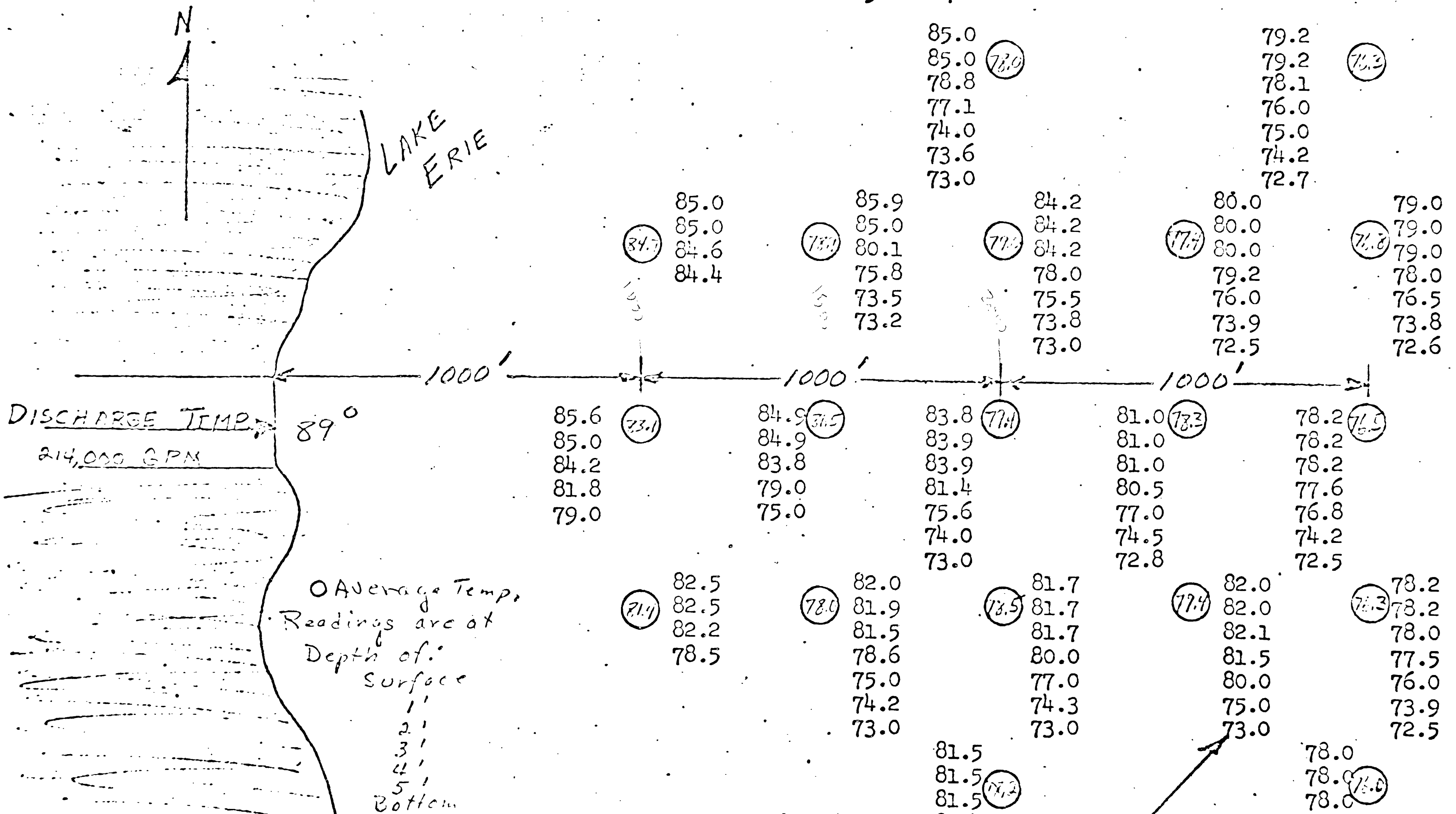
LAKE ERIE WATER TEMPERATURE STUDY

DATE: JUNE 29, 1967



LAKE ERIE WATER TEMPERATURE STUDY

DATE: JULY 20, 1967



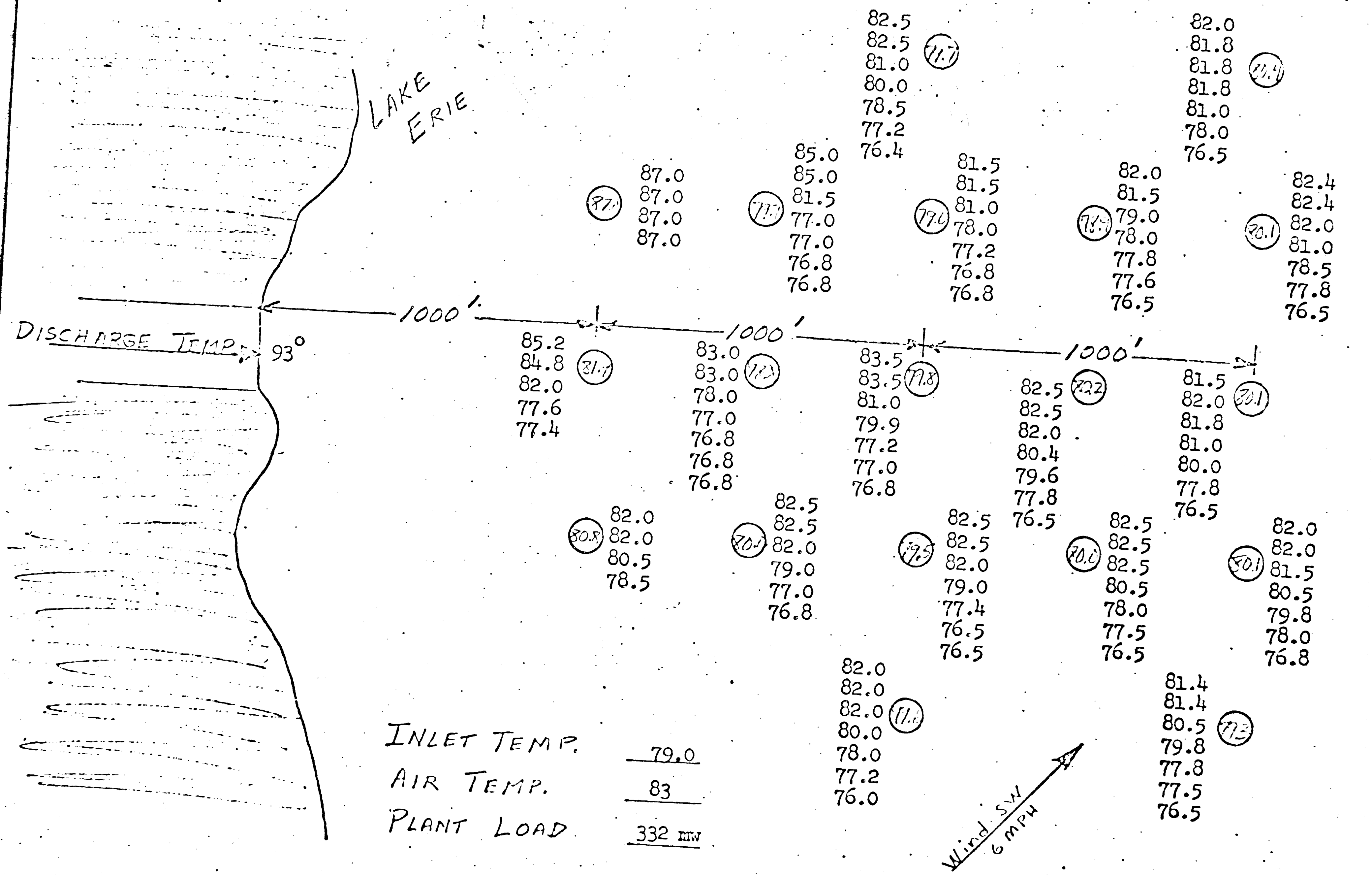
INLET TEMP. 75.8°

AIR TEMP. 72°

PLANT LOAD 329 MW

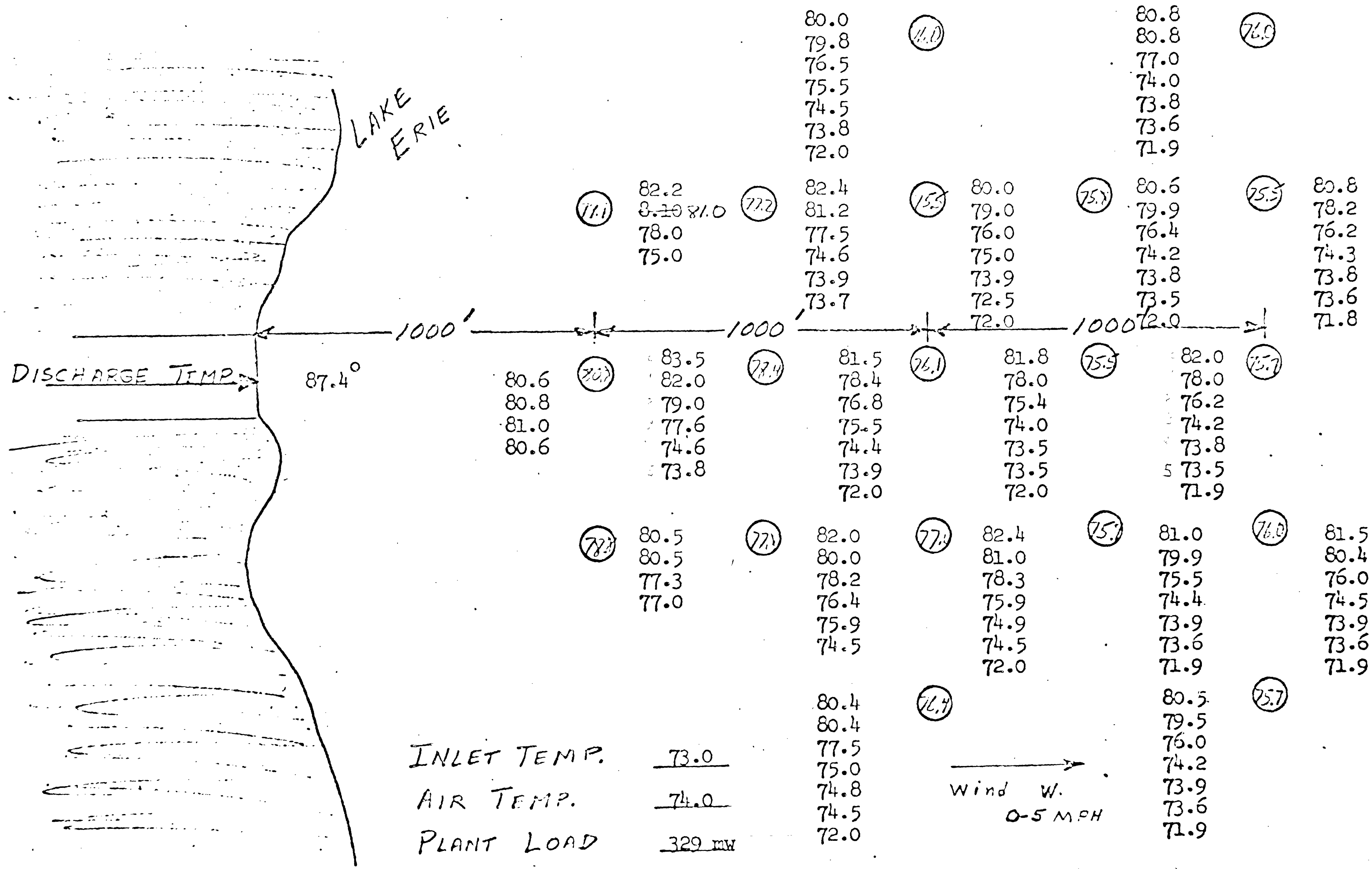
LAKE ERIE WATER TEMPERATURE STUDY

DATE: Aug. 3, 1967

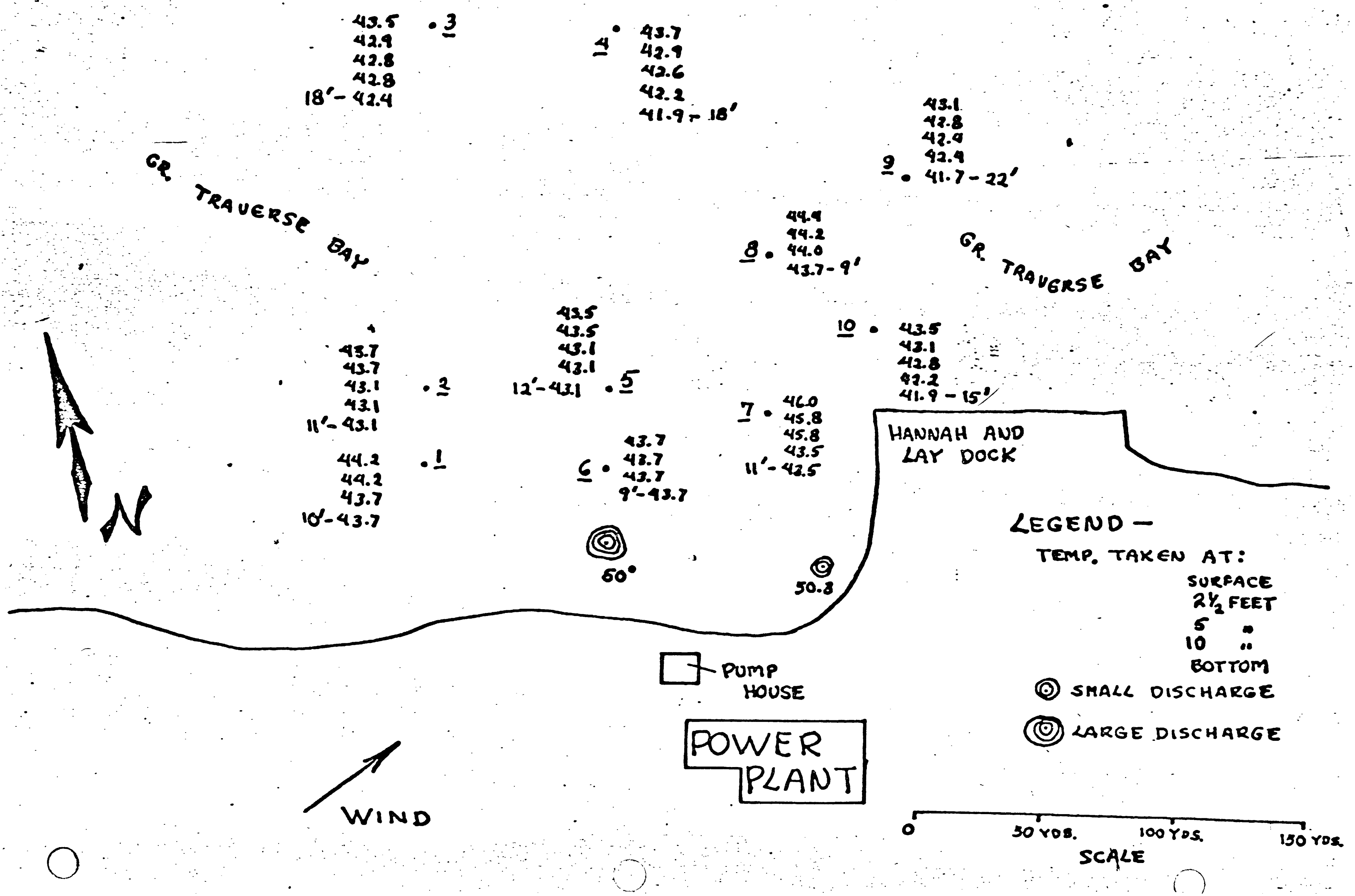


LAKE ERIE WATER TEMPERATURE STUDY

DATE: September 7, 1967



AROUND THE TRAVERSE
CITY POWER PLANT
JULY 1, 1968



Appendix E

PRELIMINARY TEMPERATURE SURVEY IN THERMAL PLUME AT BIG ROCK

17 June 1968

Wind calm   Outfall temperature 18.3°C

Ambient lake temperature: 11.7 to 11.8°C

70 yards west of outfall mouth, depth 2ft, surface 18.0°, bottom 14.0°
" " " " " " " 3 " " 17.8° " 12.0°

100 " " " " " , " 2 ", " 18.2°, " 13.8°
THERMOCLINE AT 18 INCHES

150 " " " " " , " 2 ", " 18.0°, " 13.7°

200 " " " " " , " 1.5", " 17.3°, " 15.2°

250 " " " " " , " 1.5", " 17.3°, " 16.1°

300 " " " " " , " 1.5", " 17.3°, " 16.8°

Off outfall, 200 ft offshore north, depth 5 ft, top 17.9°, bottom 13.8°
THERMOCLINE AT 2 FEET

50 yards east of outfall mouth, depth 1.5 ft, top 17.9°, botton 17.4°

75 " " " " " , 200 feet offshore north, depth 1 foot, surface 18.0°, bottom 17.8°

150 yards east, 300 ft offshore, depth 2 ft, surface 17.0°, bottom 14.9°

200 yards east, 200 ft offshore, depth 2 ft, 16.9° on top, bottom 16.9°

200 " " , 400 " " , " 2.5 ", 16.7° " ", " 13.8°
THERMOCLINE AT 9 INCHES

200 " " , 500 ft offshore, depth 3 ft, 16.3° " ", " 12.0°
THERMOCLINE AT 30 INCHES

200 " " , 600 ft offshore, depth 3 ft, 16.1° " ", " 11.9°
THERMOCLINE AT 30 INCHES

200 " " , 800 ft offshore, depth 6 ft, 16.2° " ", " 11.8°
THERMOCLINE AT 4 INCHES

200 " <u>west</u>, 800 ft offshore, depth 15 ft, 16.1°" ", " 11.7°
THERMOCLINE AT 30 INCHES

Distances this day were estimated.

THERMOCLINE = A sharp temperature discontinuity where all but a few tenths degree of the total temperature difference occurred.

TEMPERATURE SURVEY IN THERMAL PLUME AT BIG ROCK

18 June 1968

Wind south 5-10 mph; ambient lake temperature 10.7 to 11.3°C
Outfall temperature 18.0°C

Distances along shore are paced; distances offshore by paying out measured line as dinghy drifted.

In outfall mouth, 18.0° top to bottom

100 ft offshore north of outfall mouth,	surface	18.0°	
160 " " " " " " ,	"	18.0°	
200 " " " " " " ,	"	18.0°	
300 " " " " " " ,	"	17.9°	
400 " " " " " " ,	"	15.1°	
600 " " " " " " ,	"	15.9°	ok
800 " " " " " " ,	"	14.5°	
850 " " " " " " ,	"	13.9°	
950 " " " " " " ,	"	11.3°	
1150 " " " " " " ,	"	11.8°	ok
1450 " " " " " " ,	"	11.3°	
1850 " " " " " " ,	"	11.2°	

100 yards west of outfall,	100 ft north offshore,	surface	11.1°
	160 " " " ,	"	11.1°
	200 " " " ,	"	10.9°
	300 " " " ,	"	10.8°
	360 " " " ,	"	10.8°
	400 " " " ,	"	10.8°
	600 " " " ,	"	10.7°
	700 " " " ,	"	10.7°
	760 " " " ,	"	10.7°
	800 " " " ,	"	10.7°
	850 " " " ,	"	10.7°
200 yards east of outfall,	100 " " " ,	"	13.0°
	160 " " " ,	"	12.9°
	200 " " " ,	"	12.9°
	300 " " " ,	"	13.6°
	400 " " " ,	"	15.2°
	500 " " " ,	"	16.0°
	600 " " " ,	"	16.2°
	700 " " " ,	"	15.4°
	760 " " " ,	"	14.3°
	800 " " " ,	"	12.5°
	850 " " " ,	"	12.2°
	1050 " " " ,	"	12.0°
	1350 " " " ,	"	11.8°
	1750 " " " ,	"	11.3°
	2050 " " " ,	"	11.3°

Location	Distance from shore	Temperature
400 yards east of outfall (opposite tip of first point)	100 ft north off shore, surface	14.[illegible]°
	120 " " " , "	14.0°
	200 " " " , "	13.9°
	300 " " " , "	13.5°
	400 " " " , "	13.0°
	450 " " " , "	13.0°
	500 " " " , "	12.8°
	600 " " " , "	12.3°
	700 " " " , "	11.8°
	800 " " " , "	11.3°
	900 " " " , "	11.3°
500 yards east of outfall,	100 ft north offshore, surface	12.9°
	150 " " " , "	12.8°
	200 " " " , "	[illegible]
	300 " " " , "	11.[illegible]°
	400 " " " , "	11.2°
	500 " " " , "	11.2°
600 yards east of outfall,	[illegible] " " " , "	11.8°
	[illegible] " " " , "	11.[illegible]°
	[illegible] " " " , "	11.2°
	[illegible] " " " , "	11.1°
	340 " " " , "	11.1°
700 yards east of outfall,	100 " " " , "	12.2°
	200 " " " , "	11.9°
	300 " " " , "	11.8°
	400 " " " , "	11.7°
	500 " " " , "	11.7°
	600 " " " , "	11.6°
	700 " " " , "	11.3°
	800 " " " , "	11.3°
	900 " " " , "	11.3°

HYDROLOGICAL SURVEYS FOR THE LOCUST POINT POWER PLANT

PART II. CURRENTS AND DILUTION

John C. Ayers
and
Robert F. Anderson

Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

August 15, 1969

CURRENT STUDIES IN THE LOCUST POINT REGION

Procedure

Field work was carried out from a Boston Whaler outboard cruiser.

Currents were measured with a shortened version of the U. S. Coast and Geodetic Survey current pole and Rhodamine B dye.

The current poles consisted of 4-foot lengths of commercial 2x4 dimension stock. Each carried a brick at its lower end for ballast and for extra current drag. The poles floated vertically with about 10 inches exposed above the water surface. Each pole was numbered and carried a small orange pennant at its top.

The current poles were set under different wind conditions in front of the plant property in positions so chosen that they would pass over the position of the future plant discharge plume.

Positions of setting, positions during the run, and positions of pole recovery were determined by sextant fixes to charted landmarks ashore. Setting positions and during-run positions are indicated by small dots along the trajectory of each pole in Figures 1 through 20. Recovery positions are indicated by arrowheads in these figures. The identifying pole numbers are indicated at either the start or finish of the pole run.

Wind velocities were measured in the field with a hand-held anemometer.

Each pole was followed as long as the conditions of the day permitted.

Results

The results consist of current pole runs with simultaneous wind data. Runs were made on July 18, 19, 23, 25, 26, 30, 31, August 1, 6, 13, 14, 15, September 6, 10, 12, 13, 17, and 18. Current velocity results and wind data are presented in Tables 3 through 21 and the trajectories of the current poles are given in Figures 1 through 20.

On July 18 there were two current pole runs with resetting between.

The wind directions under which results were obtained are summarized in Table 1.

Table 1. Wind directions under which results were obtained.

Date	Winds from
July 18, 1968	SW 220°
July 19, 1968	NNW 330°
July 23, 1968	E 90°
July 25, 1968	ENE 60°
July 26, 1968	NE 40°
July 30, 1968	E 90°
July 31, 1968	SSW 210°
Aug. 1, 1968	NE 45°
Aug. 6, 1968	WSW 240°
Aug. 8, 1968	SW 200°
Aug. 13, 1968	SW 225°
Aug. 14, 1968	NNW 330°
Aug. 15, 1968	ENE 75°
Sept. 6, 1968	WSW 250°
Sept. 10, 1968	SW 220°
Sept. 12, 1968	NW 315°
Sept. 12,13, 1968	NW 315°
Sept. 17, 1968	SSE 150°
Sept. 18, 1968	SSE 150°

At the Davis-Besse plant site the missing wind directions (N, SE, S, and W) are well enough bracketed by observed winds that the currents there may be considered quite well known.

On 12 September both a dye patch and a set of current poles were followed simultaneously. Figures 16, 17 and 18 show the almost identical movements of the two kinds of current indicators. The poles were allowed to run overnight and were recovered on 13 September.

Only four readings of dye concentration in the dye patch were obtained before it faded into the background reading. Positions of the patch were fixed four more times after reading of concentration was discontinued.

As a test of the general validity of our results we have computed mean current speeds as percentages of the mean winds. Primarily this is a test of whether direct wind pressure on the emergent portion of the current pole was introducing spurious elements of speed. If the indicated current speeds appear correct, then the poles were probably moving with the current alone. Moving with the current alone they would have little or no directional error from direct wind pressure. This test is shown in Table 2.

Table 2. Ratios of daily mean current and wind velocities.

Date	Mean Current	Mean Wind	Current/Wind
July 18, 1968	0.378 mph	14.5 mph	2.60%
July 19, 1968	0.545	14.5	3.76%
July 23, 1968	0.418	10.5	4.00%
July 25, 1968	0.210	13.0	1.60%
July 26, 1968	0.296	6.0	4.90%
July 30, 1968	0.353	13.0	2.70%
July 31, 1968	0.265	14.5	1.80%
Aug. 1, 1968	0.207	8.0	2.60%
Aug. 6, 1968	0.570	12.0	4.80%
Aug. 8, 1968	0.230	8.0	2.90%
Aug. 13, 1968	0.209	9.5	2.20%
Aug. 14, 1968	0.308	6.0	5.10%
Aug. 15, 1968	0.550	14.5	3.80%
Sept. 6, 1968	0.213	10.5	2.00%
Sept. 10, 1968	0.164	8.0	2.10%
Sept. 12, 1968	0.310	6.0	5.20%
Sept. 12,13, 1968	0.218	6.0	3.60%
Sept. 17, 1968	0.373	12.0	3.10%
Sept. 18, 1968	0.490	17.0	2.90%
		Grand Mean	3.25%

The norm to which the test is compared is the finding in Lake Erie that the mean value of surface current is "about 2%" of the wind velocity (see Hutchinson, A Treatise on Limnology, Volume I, John Wiley & Sons, New York, 1957, page 291). Within the limitations of the norm our results appear to be valid.

Conclusions

The current poles used appear to have contributed valid data.

Under most wind directions the local currents at Locust Point are downwind. Under winds from northeast, eastnortheast and east, however, water is driven into the embayment between Port Clinton and Locust Point and from there slides away along shore in a northwestward direction. Under these winds the local currents at Locust Point are dominated by the escapement of water from the embayment. Figures 3, 4, 5, 6, 8, and 13 show this effect.

It is noted that the runs on 12-13 September under northwest wind were deflected lakeward away from the Camp Perry water intake. It appears that there may be clockwise eddy set up along the shore near Camp Perry under this wind.

On the 26th of June, under a northeast wind the Toussaint River was discharging a plume of warm discolored water which tailed off northward along the shore and cooled as it went. It is shown in Figure 5.

Table 3

Figure 1

July 18, 1968

Wind - SW 220°

Table 3. July 18, 1968. Wind - SW 220°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
7	2775	.53	1	47	.36	220°	10-15	12-17
6	2400	.45	1	36	.33	"	"	"
2	3600	.68	1	56	.44	"	"	"
3	1450	.28	1	16	.24	"	"	"
Reset								
3	4800	.91	3	57	.26	"	"	"
7	7175	1.36	3	29	.44	"	"	"
6	7200	1.36	3	11	.44	"	"	"
2	6500	1.23	2	43	.51	"	"	"

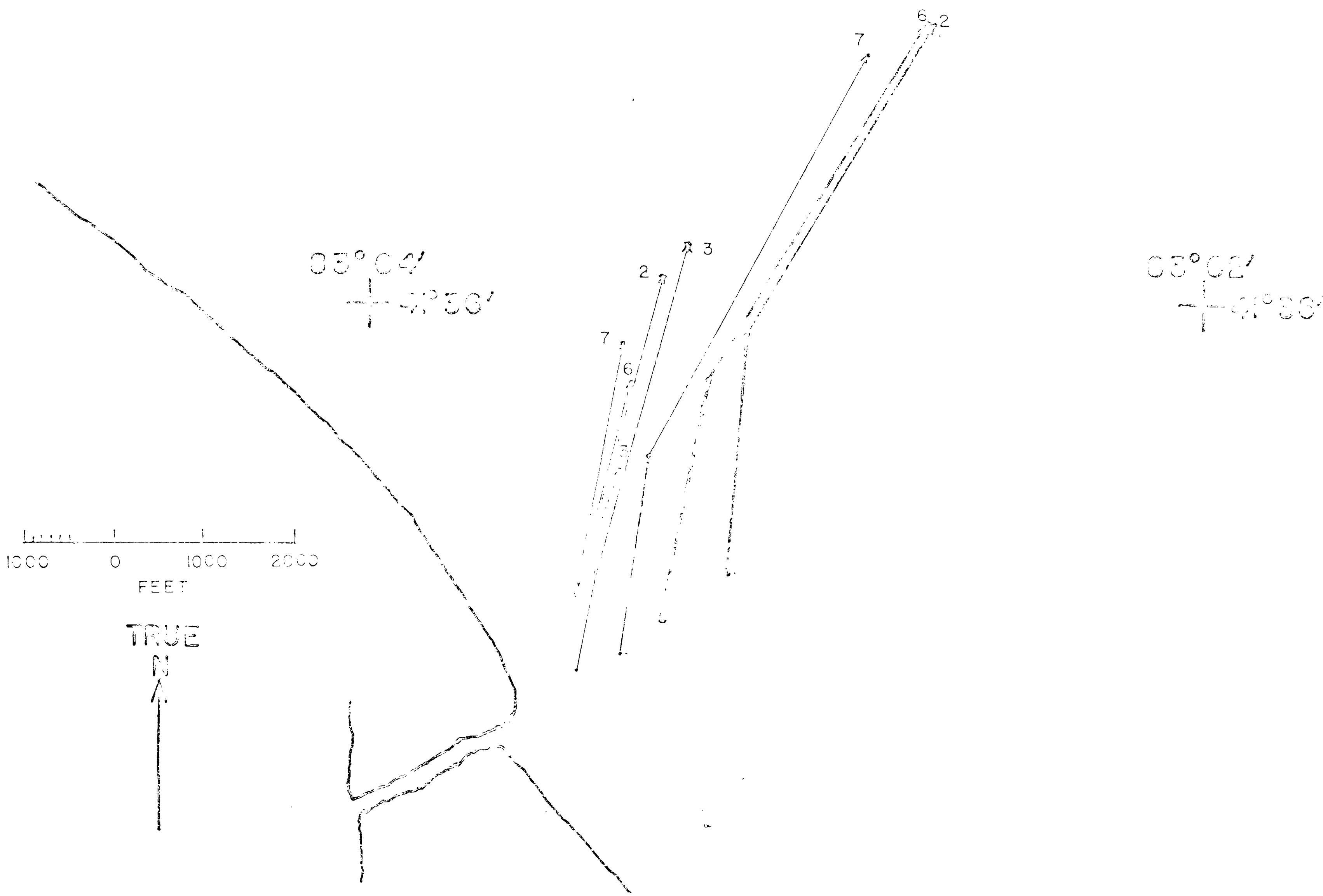


Figure 1. Pole Runs, 18 July 1968. Wind SW.

Table 4

Figure 2

July 19, 1968

Wind - NNW 330°

Table 4. July 19, 1968. Wind - NNW 330°.

Pole	Distance traveled		Elapsed time		Current velocity	Wind		
						Dir.	velocity	
no.	feet	miles	hr.	min.	(mph)	from	knots	mph
1	6525	1.24	3	15	.39	330°	10-15	12-17
3	6400	1.21	2	06	.59	"	"	"
8	6650	1.26	2	08	.61	"	"	"
7	6200	1.17	2	00	.59	"	"	"

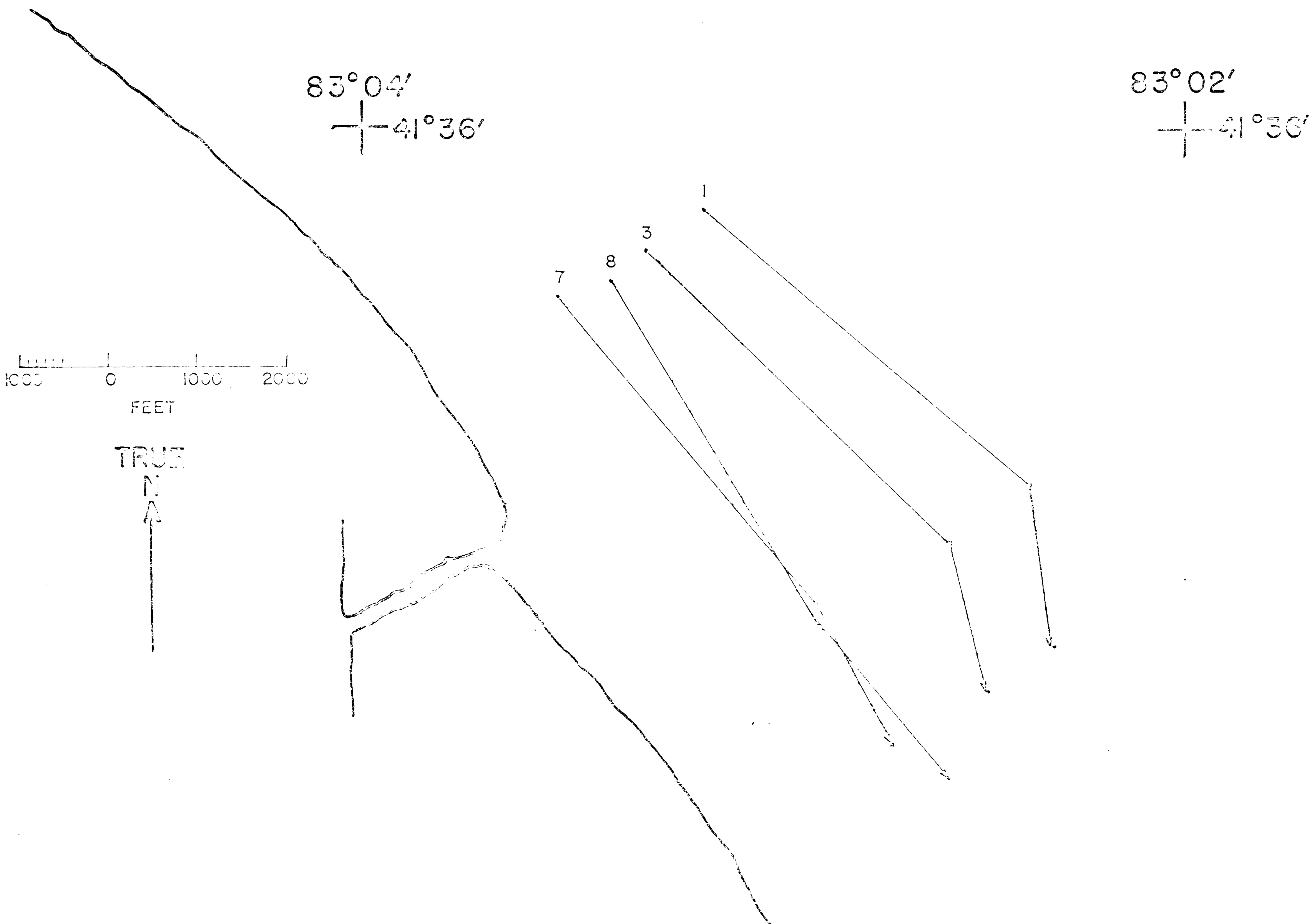


Figure 2. Pole Runs, 19 July 1968. Wind NNW.

Table 5

Figure 3

July 23, 1968

Wind - E 90°

Table 5. July 23, 1968. Wind - E 90°.

Pole	Distance traveled		Elapsed time		Current velocity	Wind		
						Dir.	velocity	
no.	feet	miles	hr.	min.	(mph)	from	knots	mph
6	13,450	2.55	5	27	.48	90°	8-10	9-12
3	12,300	2.33	5	06	.46	"	"	"
7	12,500	2.37	5	16	.46	"	"	"
1	10,950	2.07	5	33	.39	"	"	"
8	10,950	2.07	5	21	.40	"	"	"
9	8,950	1.70	5	24	.32	"	"	"

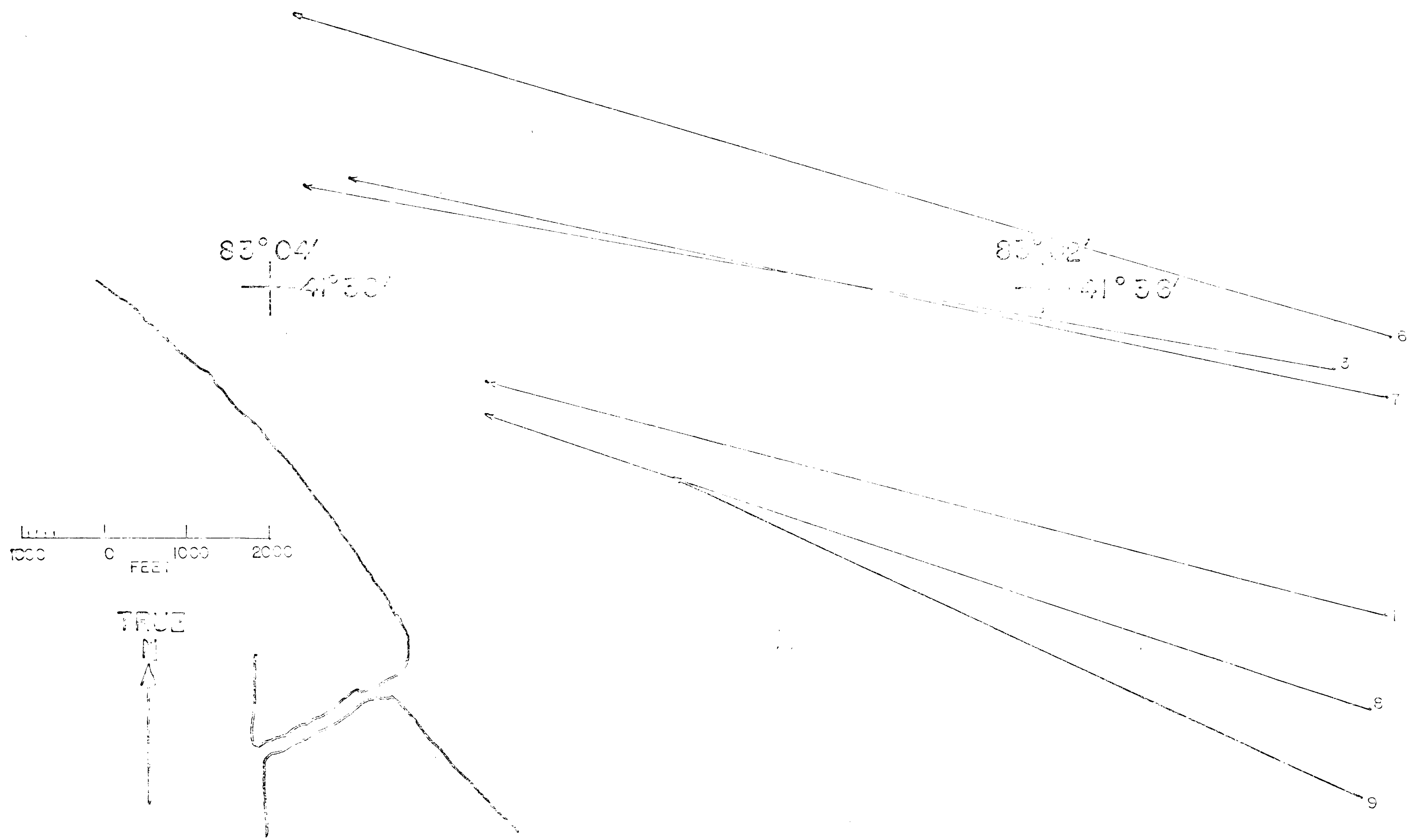


Figure 9. Pole Runs, 23 July 1968. Wind E.

Table 6

Figure 4

July 25, 1968

Wind - ENE 60°

Table 6. July 25, 1968. Wind - ENE 60°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
6	4900	.93	4	58	.20	60°	10-12	12-14
9	7325	1.39	5	40	.26	"	"	"
3	5250	99	5	32	.19	"	"	"
7	6700	1.27	6	13	.21	"	"	"
1	6870	1.30	6	42	.21	"	"	"
8	6105	1.16	6	07	.19	"	"	"

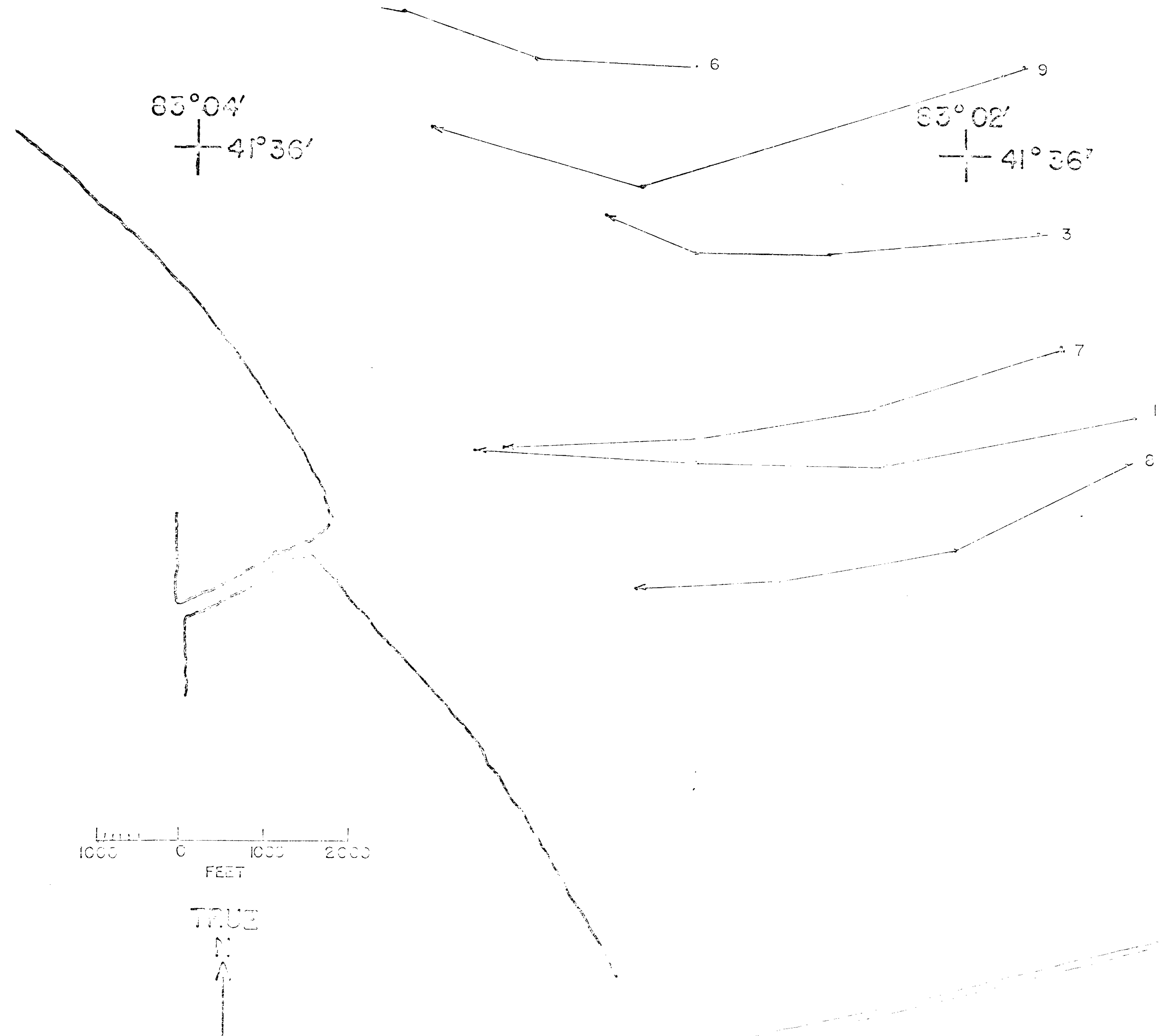


Figure 4. Pole Runs, 25 [illegible]

Table 7

Figure 5

July 26, 1968

Wind - NE 40°

Table 7. July 26, 1968. Wind - NE 40°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	mph
1	1450	.27	1	05	.26	40°	4-6	5-7
7	1900	.36	1	05	.34	"	"	"
9	1600	.30	1	05	.29	"	"	"

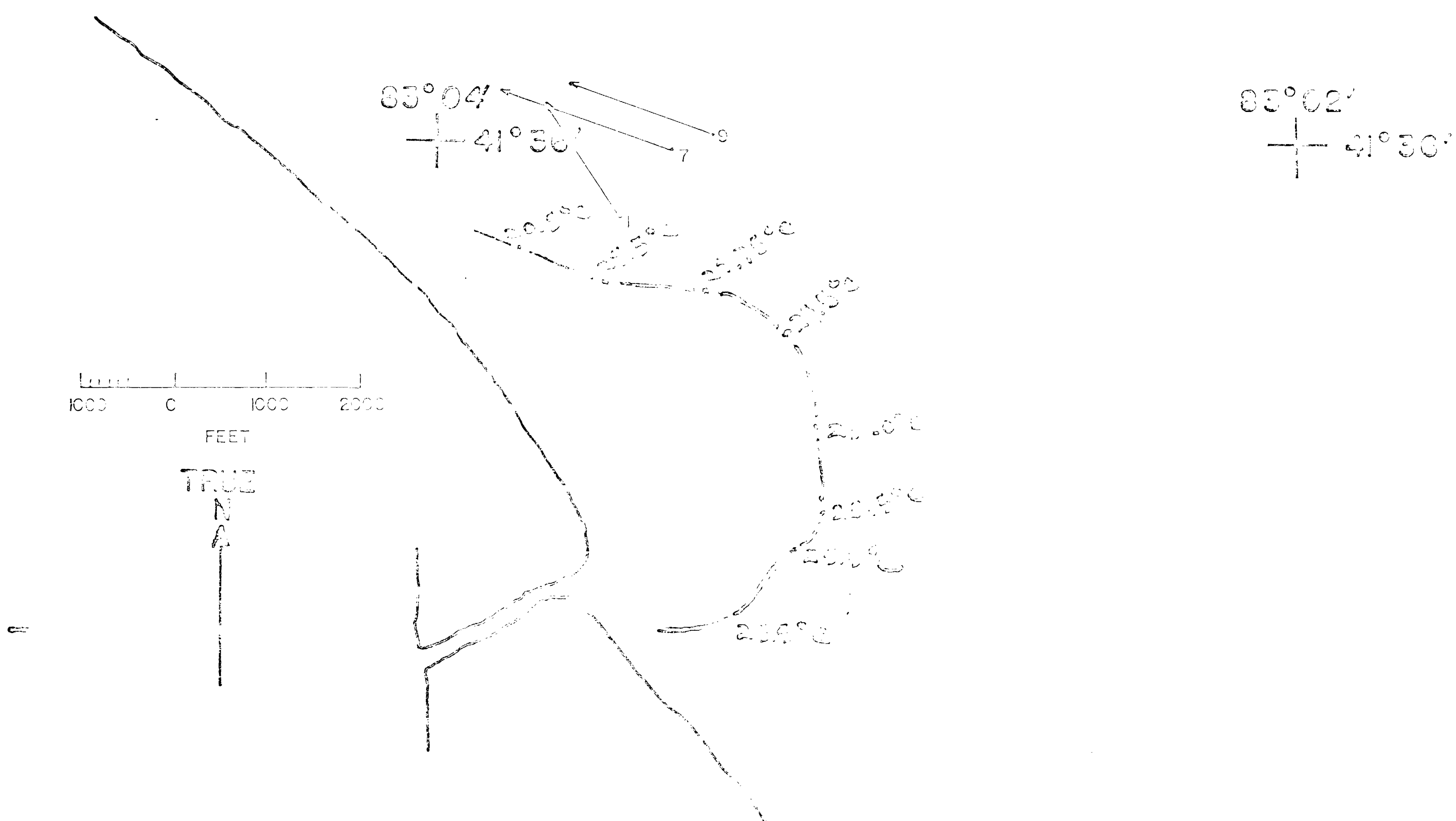


Figure 5. Pole Runs, 26 July 1968. Wind NE.

Table 8

Figure 6

July 30, 1968

Wind - E 90°

Table 8. July 30, 1968. Wind - E 90°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	7500	1.42	4	06	.35	90°	10-12	12-14
7	7925	1.50	4	11	.36	"	"	"
9	6675	1.26	3	58	.35	"	"	"

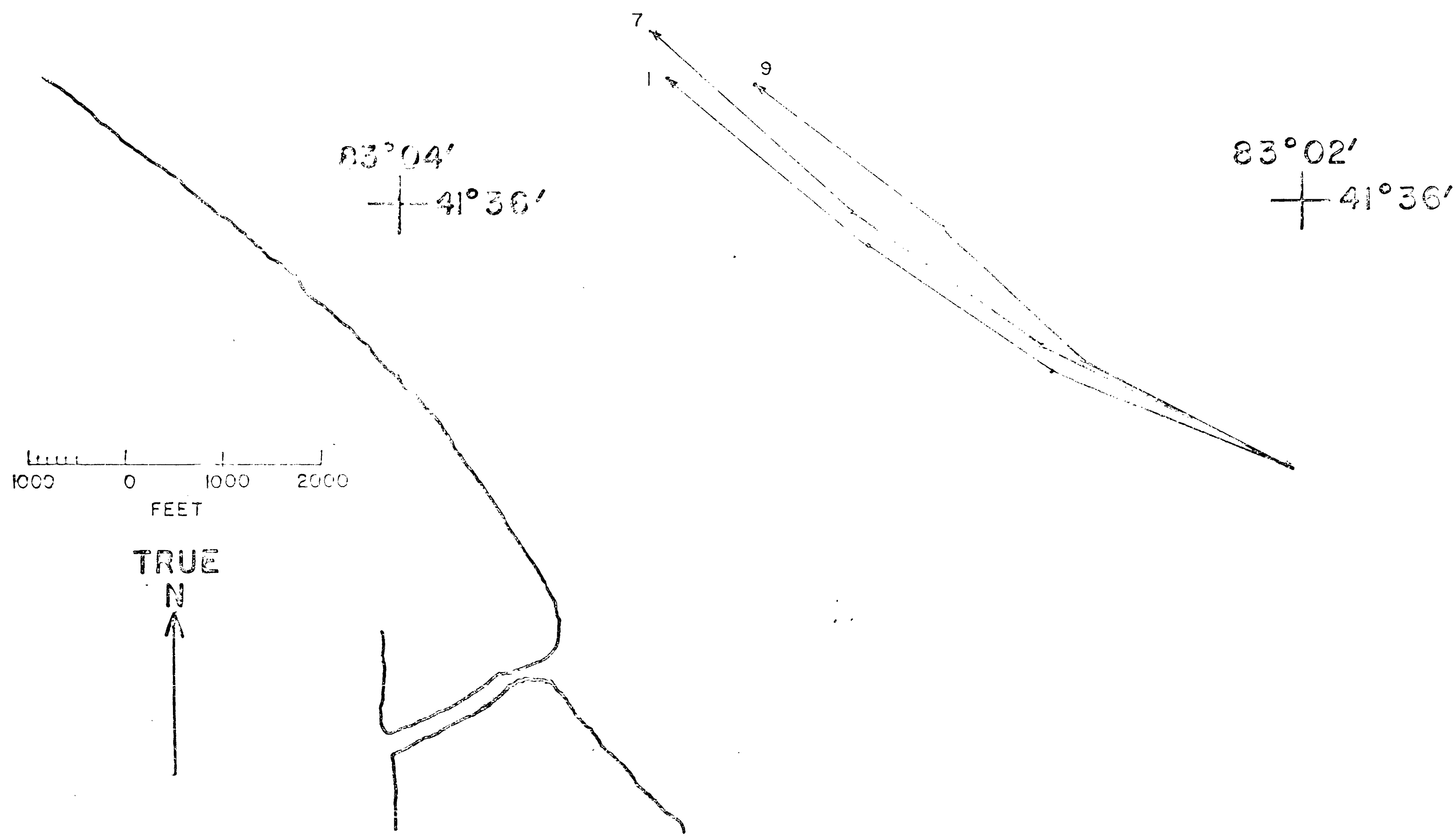


Figure 6. Pole Runs, 30 July 1968, Wind E.

Table 9

Figure 7

July 31, 1968

Wind - SSW 210°

Table 9. July 31, 1968. Wind - SSW 210°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
9	4175	.79	4	52	.17	210°	10-15	12-17
7	3850	.73	2	41	.30	"	"	"
1	3900	.74	2	36	.31	"	"	"
3	4900	.93	4	15	.22	"	"	"
8	5250	.99	4	06	.24	"	"	"
6	6200	1.17	3	35	.35	"	"	"

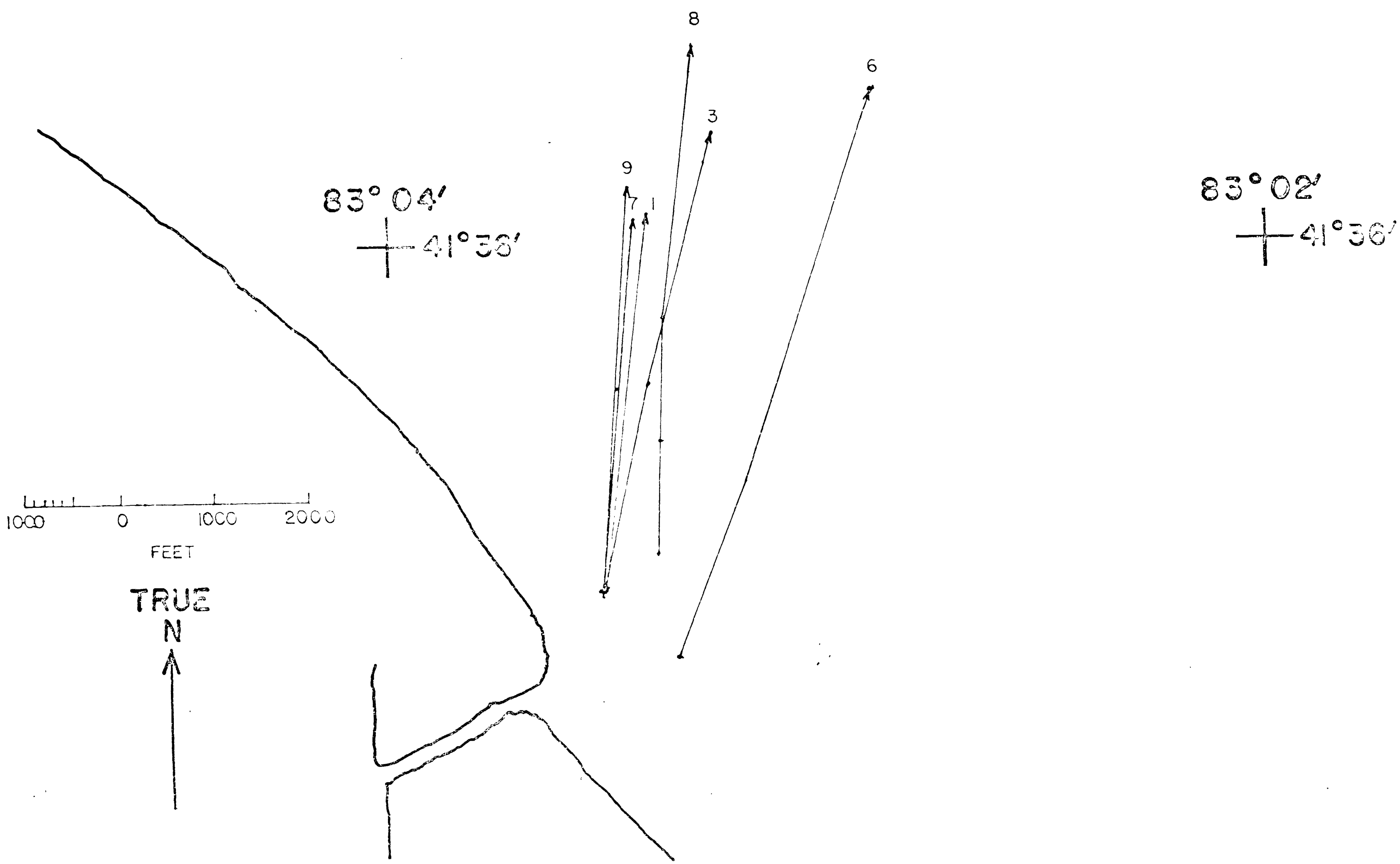


Figure 7. Pole Runs, 31 July 1968. Wind SSW.

Table 10

Figure 8

August 1, 1968

Wind - NE 45°

Table 10. August 1, 1968. Wind - NE 45°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	4000	.76	3	54	.22	45°	6-8	7-9
2	4400	.83	3	55	.23	"	"	"
9	3800	.72	4	57	.16	"	"	"
7	4450	.84	4	48	.19	"	"	"
8	4450	.84	4	44	.19	"	"	"
6	4300	.81	3	55	.23	"	"	"
3	5050	.96	4	12	.23	"	"	"

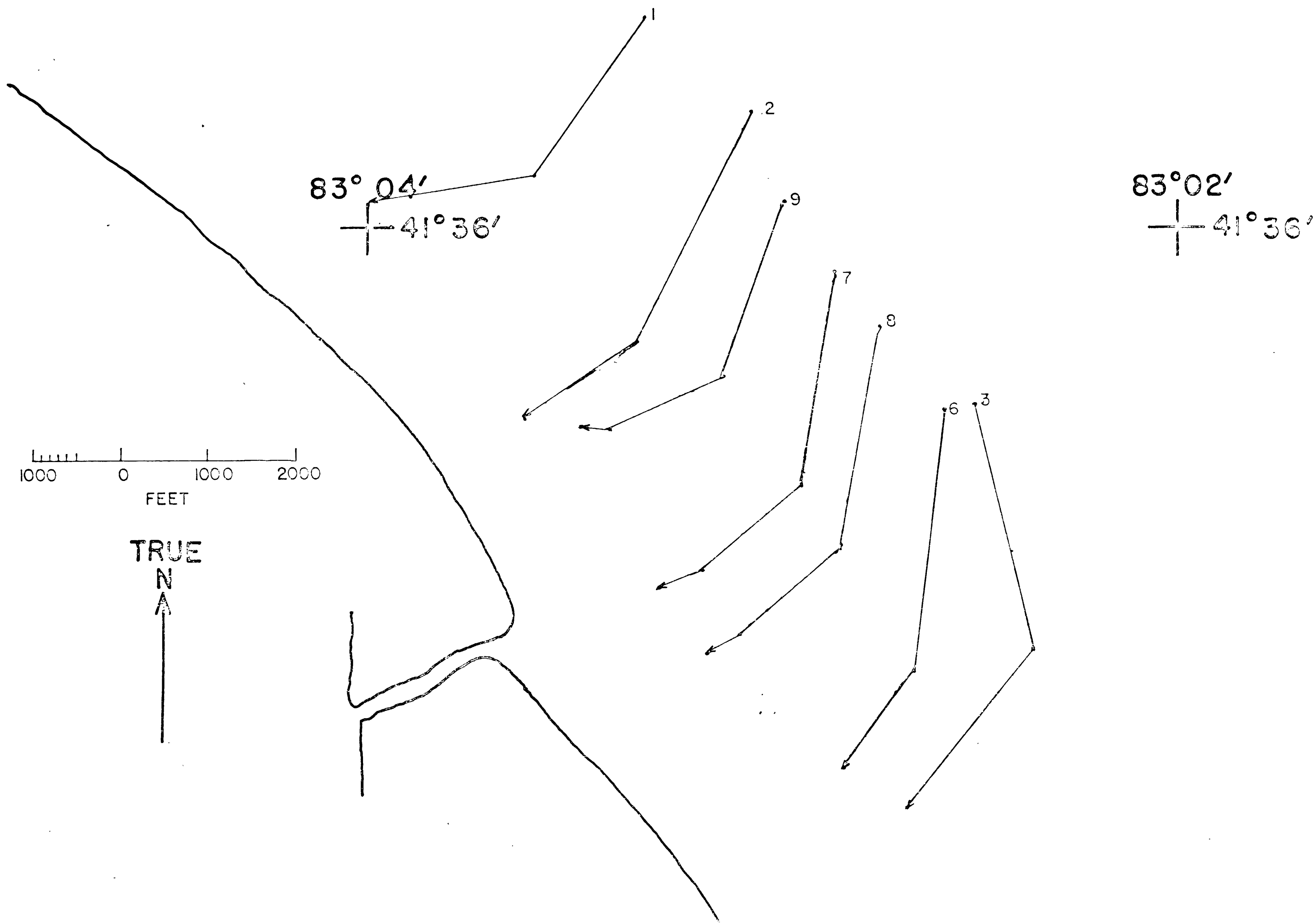


Figure 8. Pole Runs, 1 August 1968. Wind NE.

Table 11

Figure 9

August 6, 1968

Wind - WSW 240°

Table 11. August 6, 1968. Wind - WSW 240°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
7	10,675	2.02	3	48	.58	240°	10	12
1	12,175	2.31	4	39	.53	"	"	"
8	12,000	2.27	4	27	.53	"	"	"
6	11,575	2.19	3	37	.65	"	"	"
3	10,350	1.96	3	47	.56	"	"	"

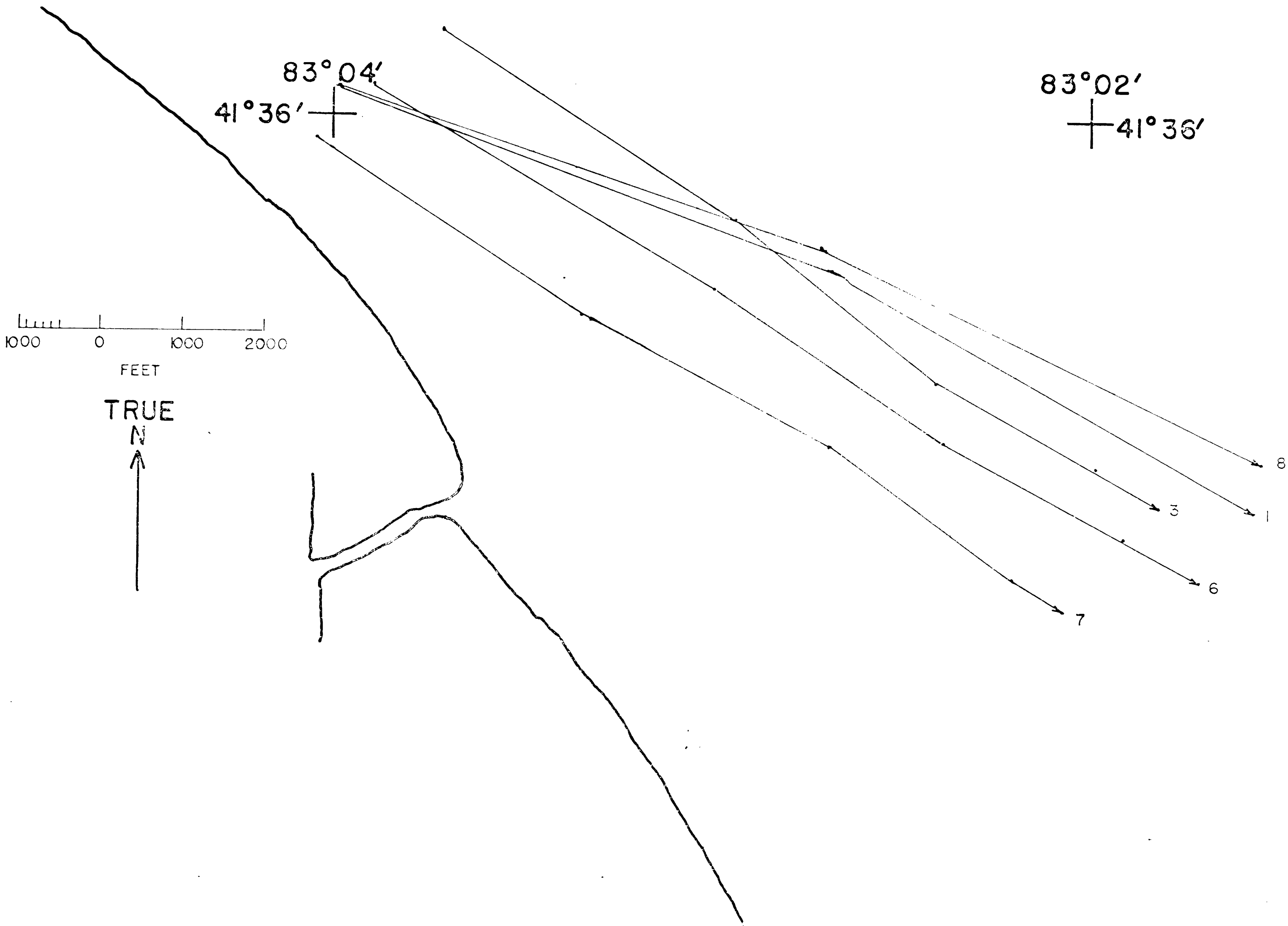


Figure 9. Pole Runs, 6 August 1968. Wind WSW.

Table 12

Figure 10

August 8, 1968

Wind - SW 200°

Table 12. August 8, 1968. Wind - SW 200°.

Pole no.	Distance feet	traveled miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
9	3025	.57	4	17	.14	200°	6-8	7-9
7	2400	.46	2	16	.21	"	"	"
3	2850	.54	2	20	.26	" "	"	"
8	2500	.47	1	52	.31	"	"	"

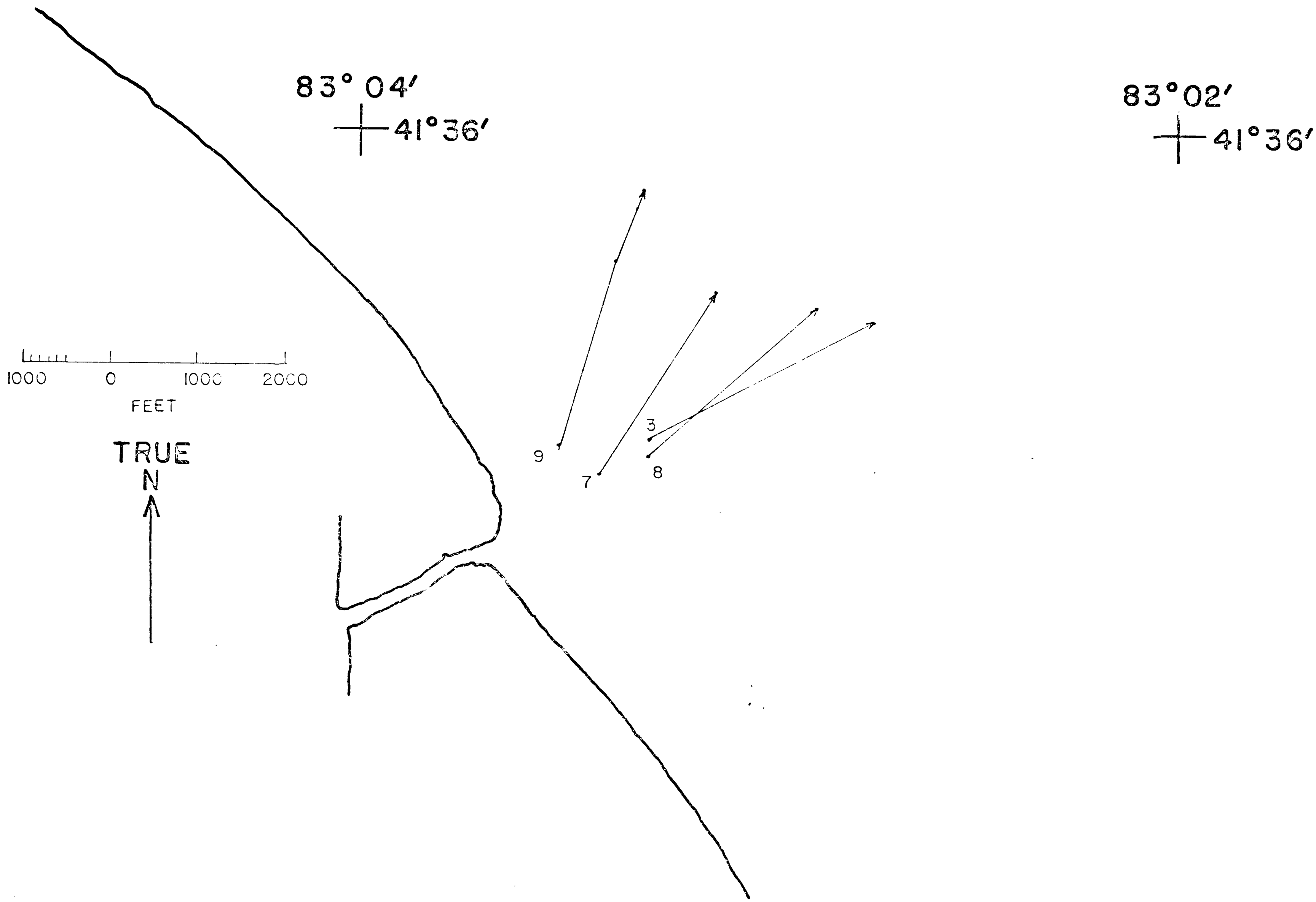


Figure 10. Pole Runs, 8 August 1968. Wind SW.

Table 13

Figure 11

August 13, 1968

Wind - SW 225°

Table 13. August 13, 1968. Wind - SW 225°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
6	7050	1.34	6	13	.22	225°	6-10	7-12
2	8600	1.63	6	06	.27	"	"	"
1	5350	1.01	5	39	.19	"	"	"
8	5950	1.13	5	34	.21	"	"	"
3	4700	.89	5	15	.17	"	"	"
9	3825	.72	4	57	.16	"	"	"
0	5450	1.03	4	30	.24	"	"	"

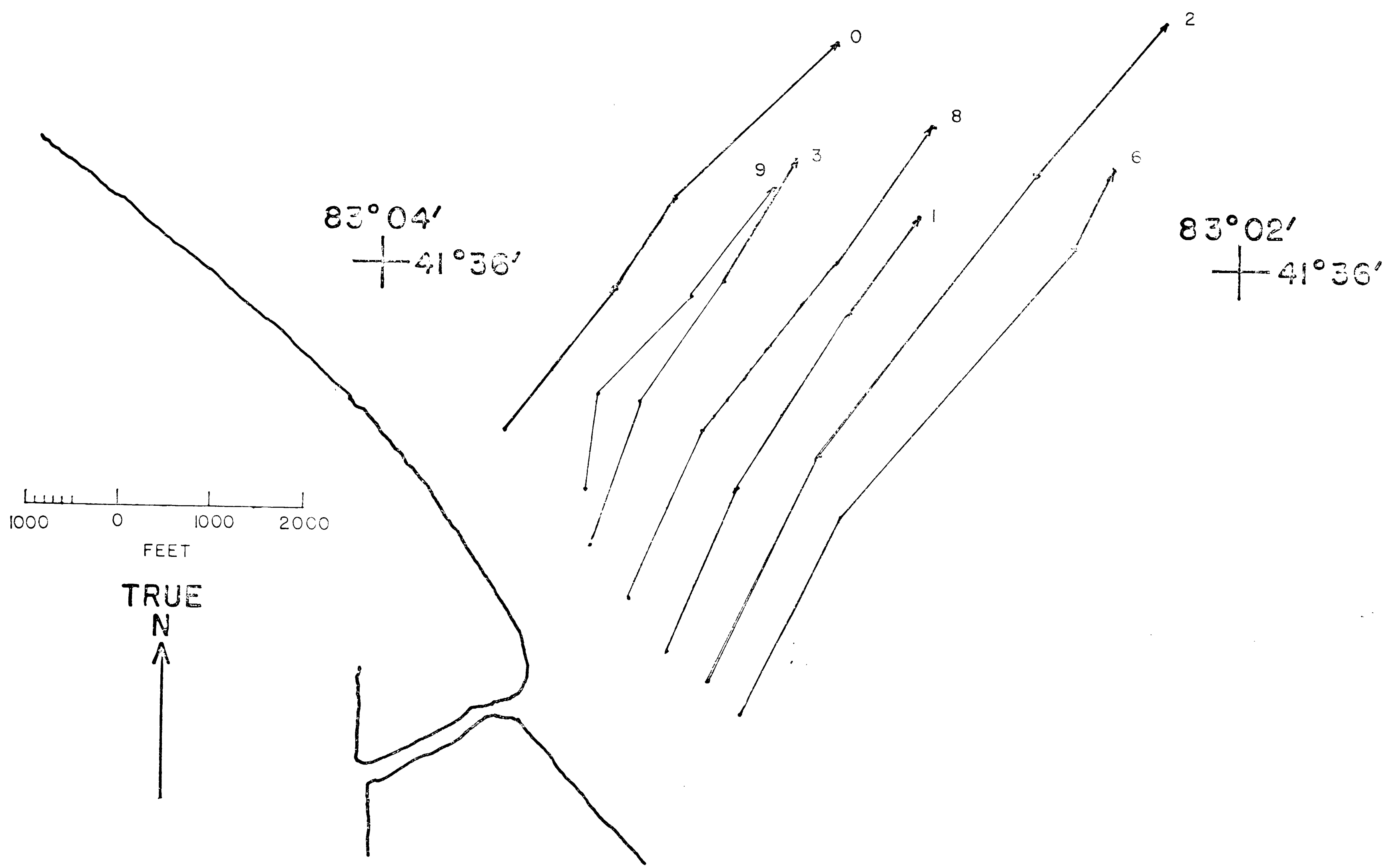


Figure 11. Pole Runs, 13 August 1968. Wind SW.

Table 14

Figure 12

August 14, 1968

Wind - NNW 330°

Table 14. August 14, 1968. Wind - NNW 330°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
13	1950	.37	1	39	.27	330°	4-6	5-7
12	2000	.38	1	29	.29	"	"	"
10	2025	.38	1	20	.32	"	"	"
11	2175	.41	1	18	.35	"	"	"

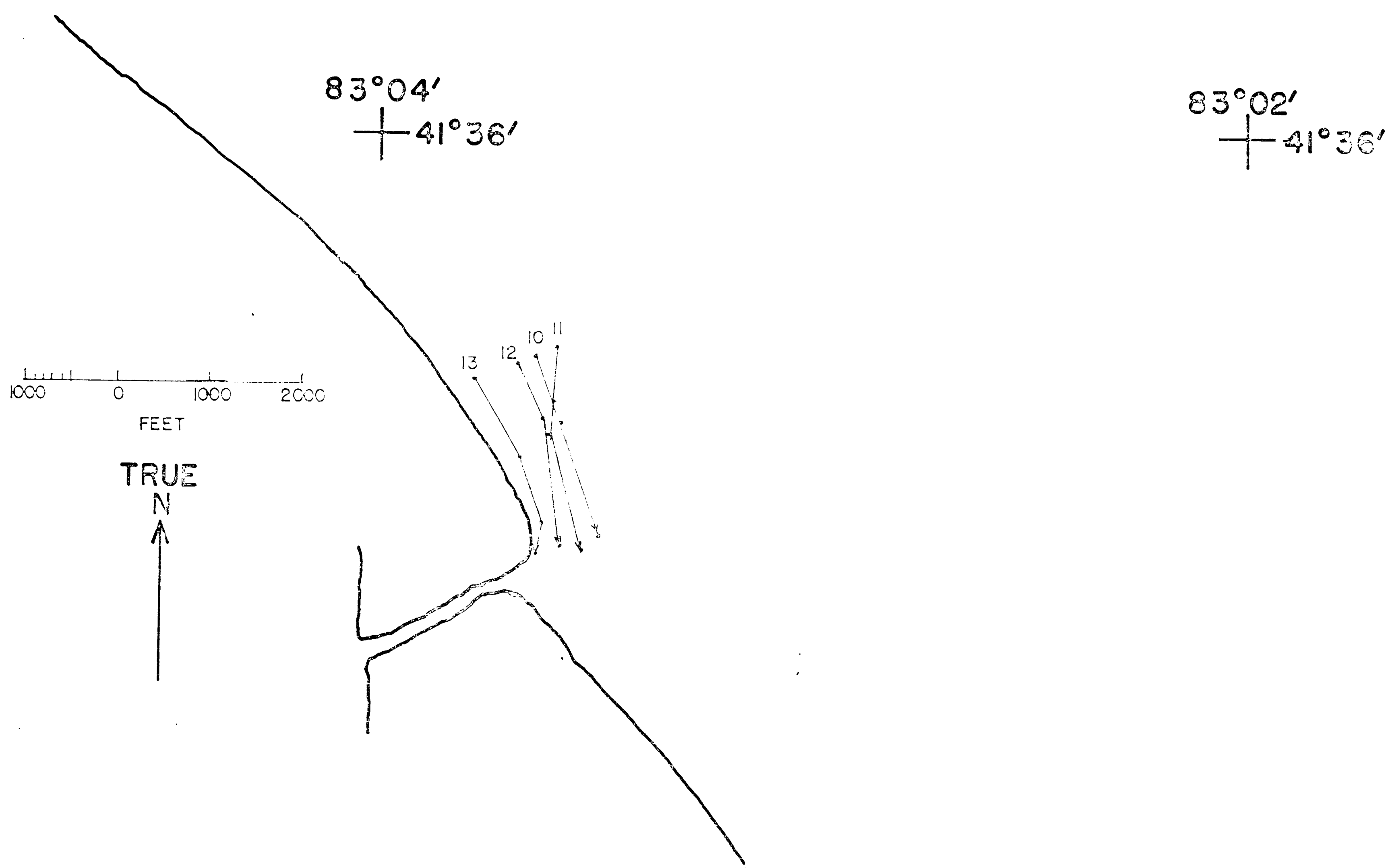


Figure 12. Pole Runs, 14 August 1968. Wind NNW.

Table 15

Figure 13

August 15, 1968

Wind - ENE 75°

Table 15. August 15, 1968. Wind - ENE 75°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	mph
14	8300	1.57	2	48	.63	75°	10-15	12-17
10	5650	1.07	2	17	.49	"	"	"
15	8675	1.64	3	25	.51	"	"	"
16	7225	1.37	2	31	.59	"	"	"
13	9375	1.78	3	38	.53	"	"	"

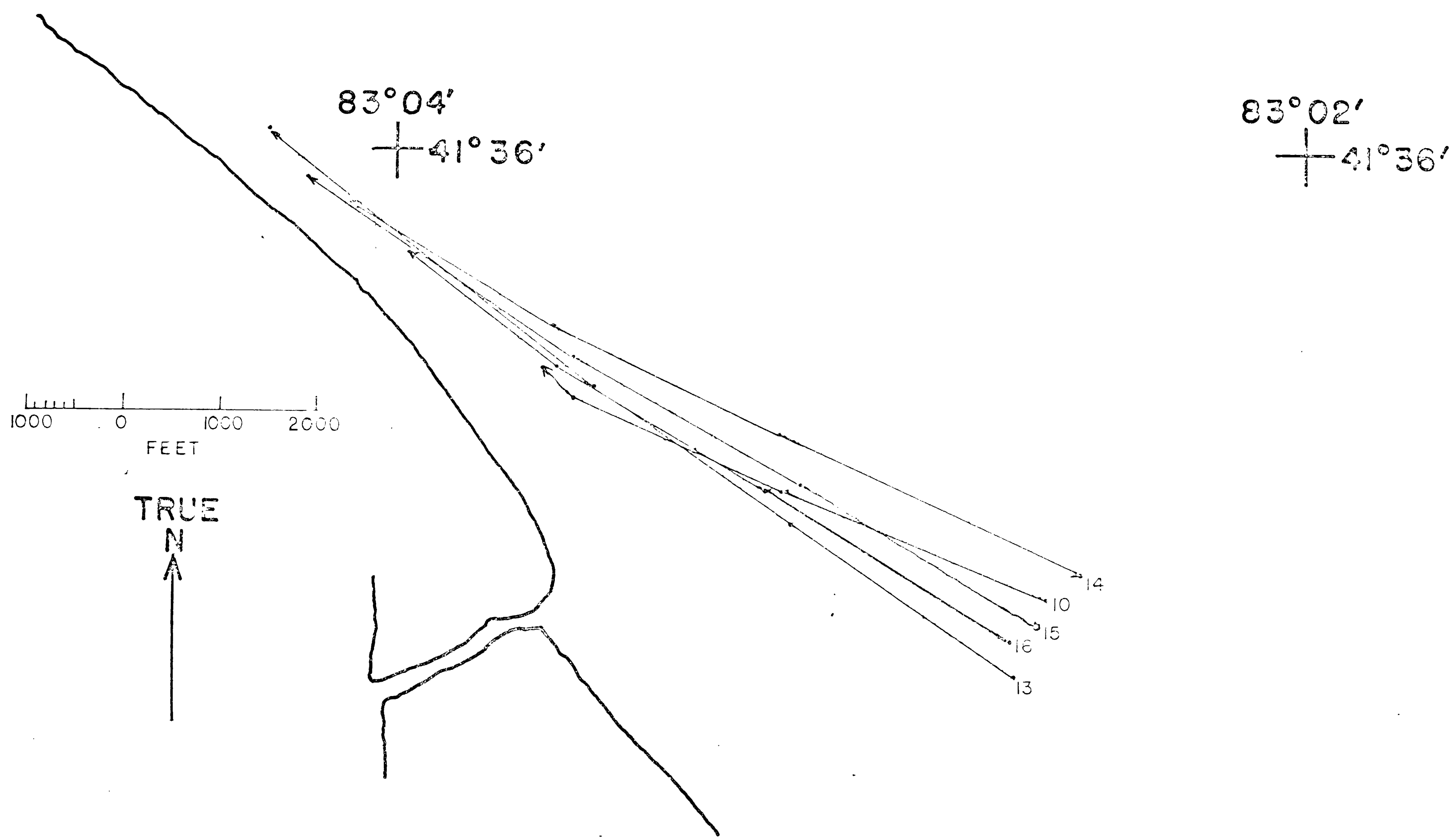


Figure 13. Pole Runs, 15 August 1968. Wind ENE.

Table 16

Figure 14

September 6, 1968

Wind - WSW 250°

Table 16. September 6, 1968. Wind - WSW 250°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
11	6000	1.14	4	01	.28	250°	8-10	9-12
10	5800	1.10	4	18	.26	"	"	"
12	6500	1.23	4	10	.30	"	"	"

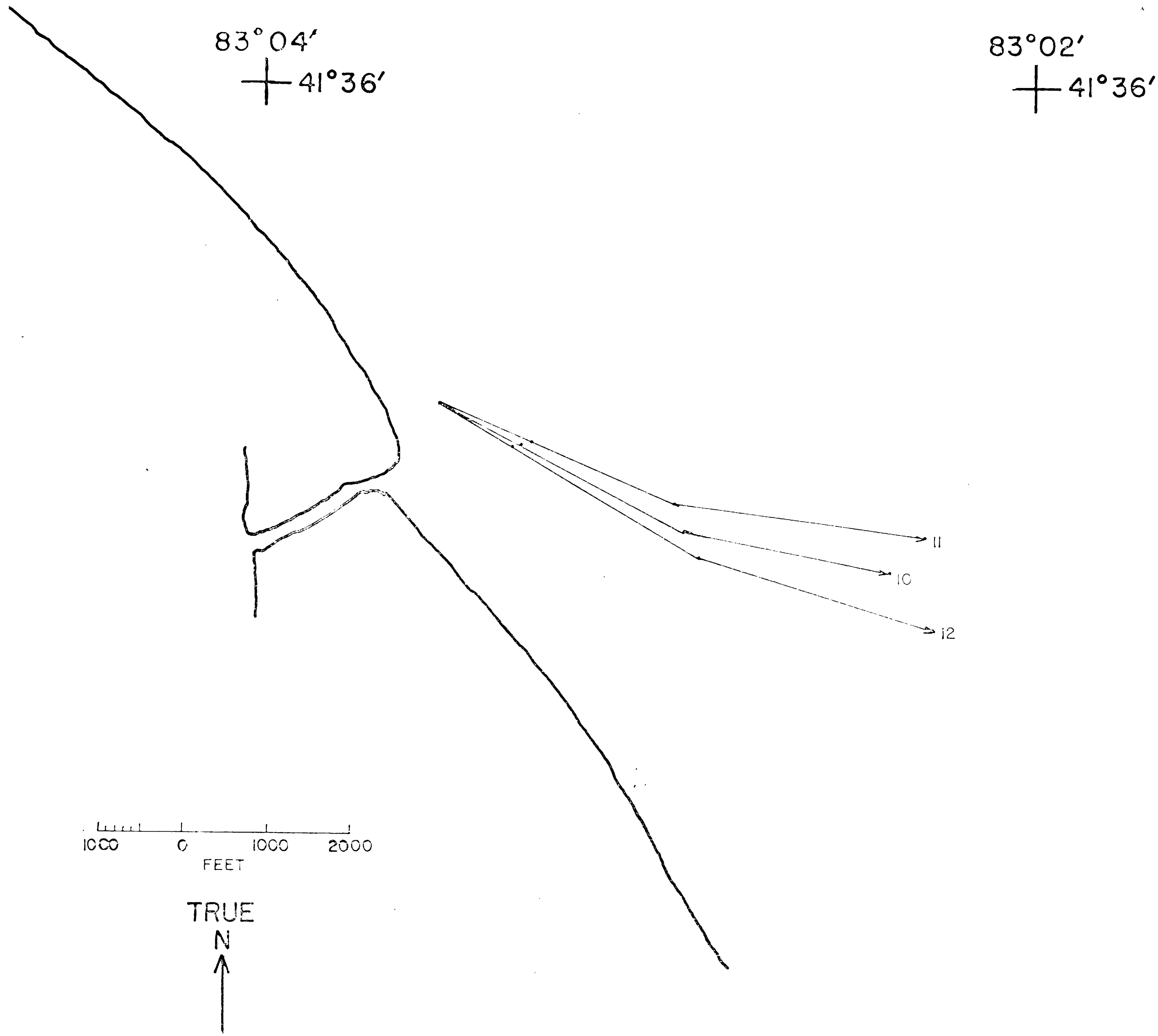


Figure 14. Pole Runs, 6 September 1968. Wind WSW.

Table 17

Figure 15

September 10, 1968

Wind - SW 220°

Table 17. September 10, 1968. Wind - SW 220°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
13	4250	.81	5	32	.15	220°	6-8	7-9
14	3900	.74	5	17	.14	"	"	"
15	5125	.97	5	10	.19	"	"	"
17	4550	.86	5	03	.17	"	"	"
10	3850	.73	3	57	.20	"	"	"
11	3800	.72	3	53	.20	"	"	"
12	2700	.51	4	07	.13	"	"	"
16	2200	.42	3	17	.13	"	"	"

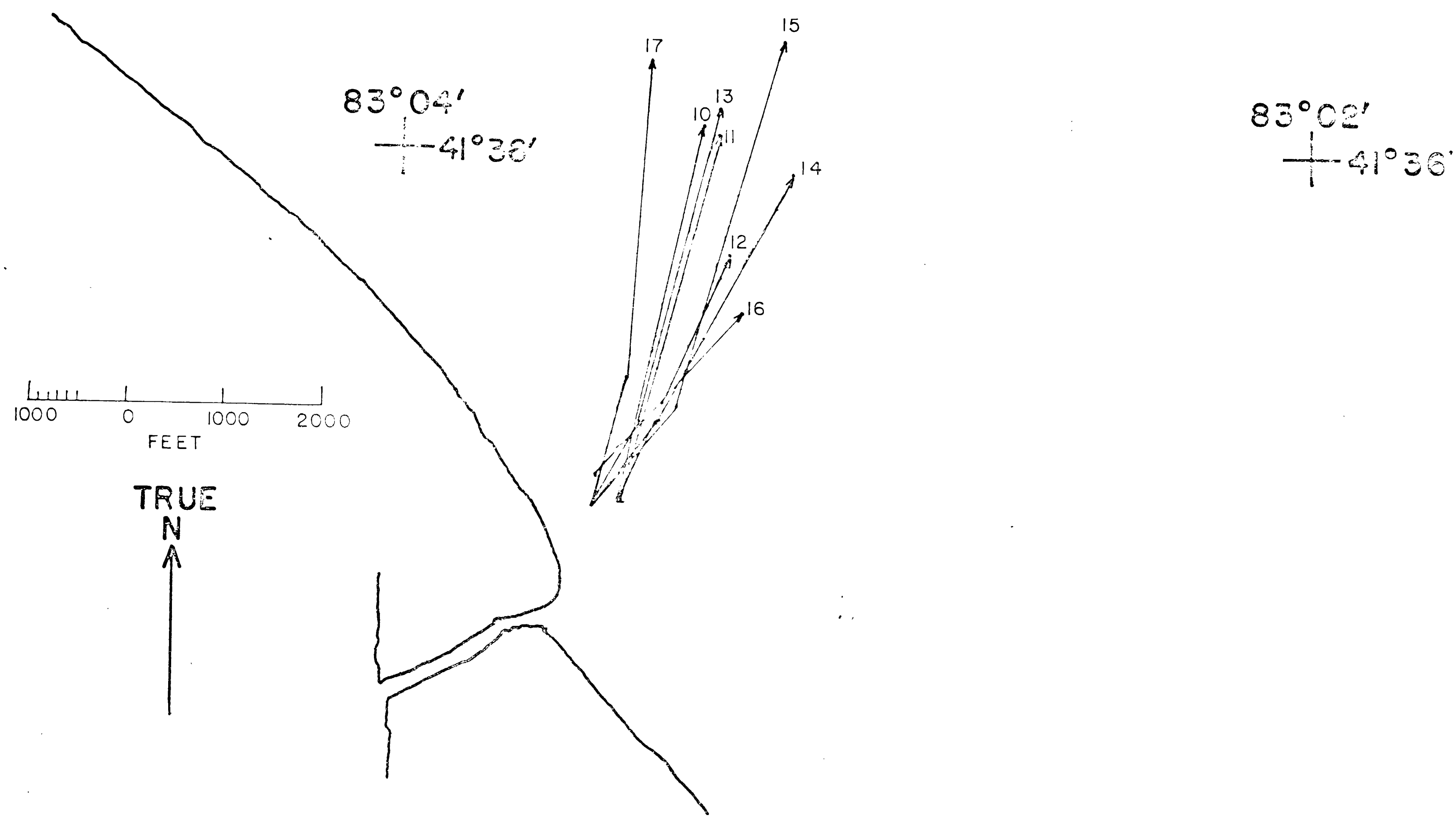


Figure 15. Pole Runs, 10 September 1968. Wind SW.

Table 18

Figures 16, 17

September 12, 13, 1968

Wind - NW 315°

Table 18. September 12, 13, 1968. Wind - NW 315°.

Pole no.	Distance feet	traveled miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
10	28,625	5.42	25	28	.21	315°	4-6	5-7
12	7,500	1.23	6	07	.20	"	"	"
13	32,250	6.11	26	54	.23	"	"	"
14	31,250	6.10	26	21	.23	"	"	"

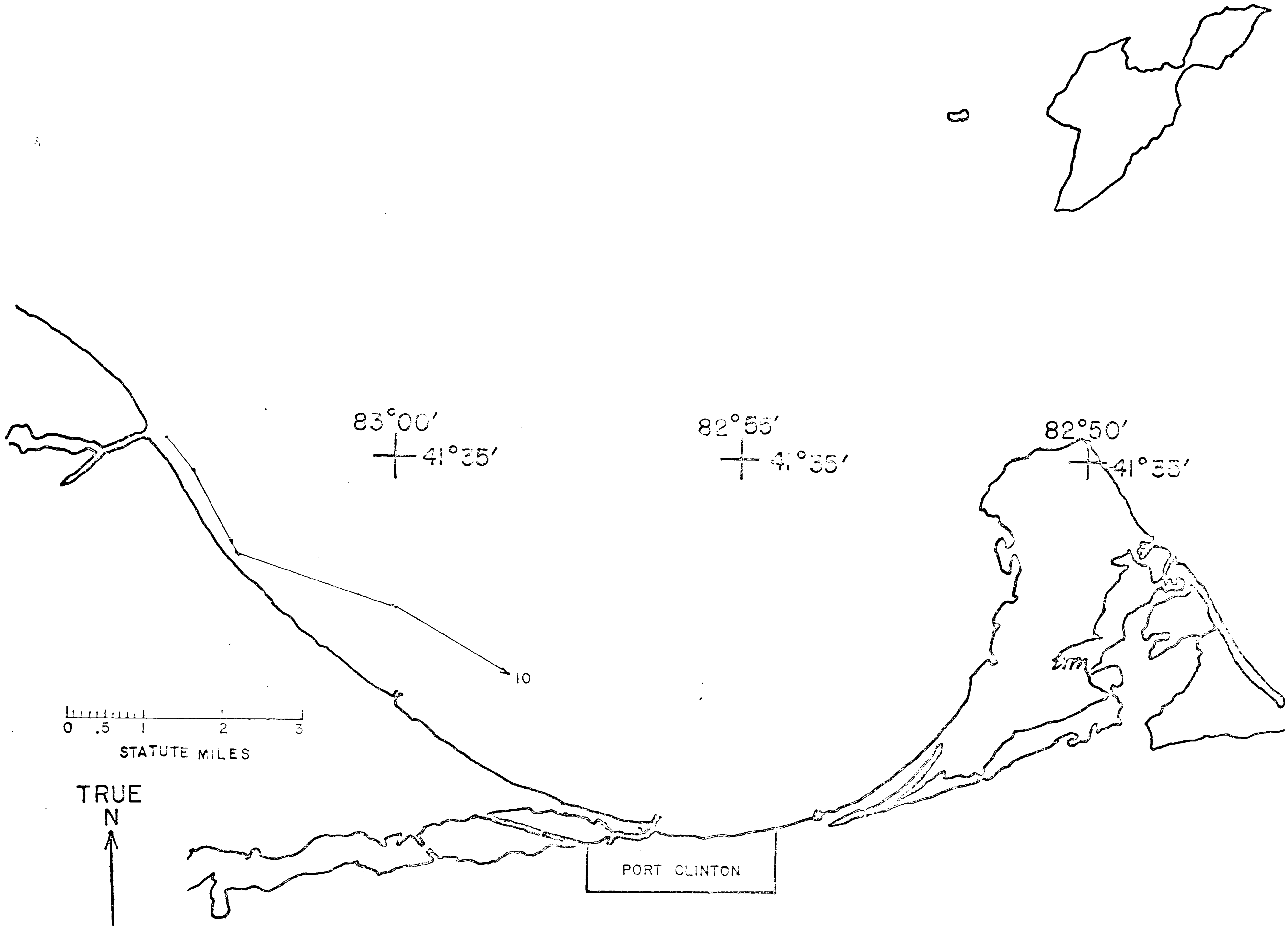


Figure 16. Run of Pole 10, 12-13 September 1968. Wind NW.

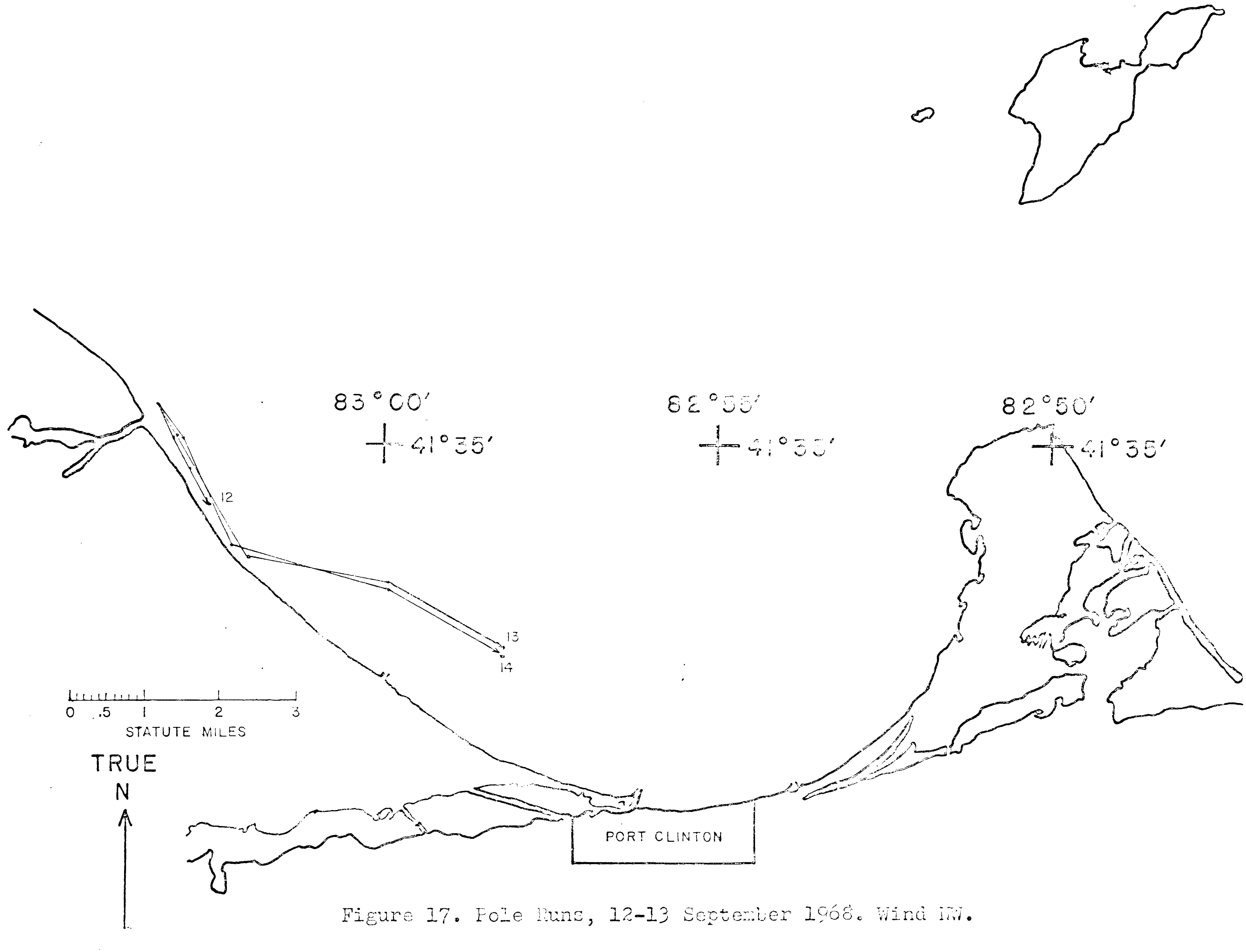


Figure 17. Pole Runs, 12-13 September 1968. Wind NW.

Table 19

Figure 18

September 12, 1968

Wind - NW 315°

Table 19. September 12, 1968. Wind - NW 315°.

Dye Positions	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	2640	.50	1	21	.41	315°	4-6	5-7
2	1840	.35	0	38	.92	"	"	"
3	528	.10	0	43	.23	"	"	"
4	1267	.24	0	45	.53	"	"	"

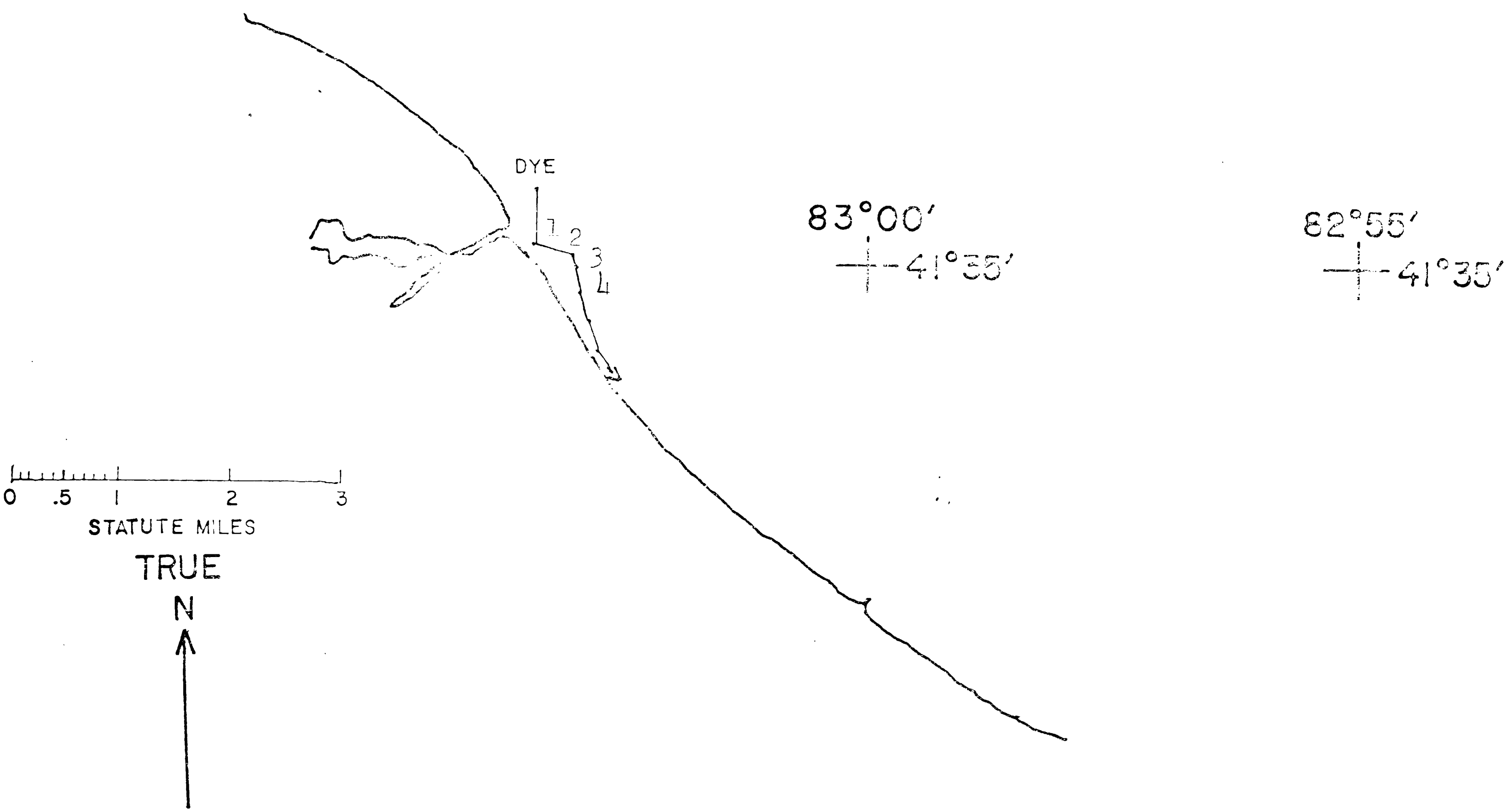


Figure 18. Dye Run, 12 September 1968. Wind NW.

Table 20

Figure 19

September 17, 1968

Wind - SSE 150°

Table 20. September 17, 1968. Wind - SSE 150°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Dir. velocity from	knots	mph
11	12,200	2.31	6	07	.38	150°	10	12
12	12,350	2.34	6	31	.37	"	"	"
16	12,475	2.36	6	21	.38	"	"	"
17	12,300	2.33	6	43	.36	"	"	"

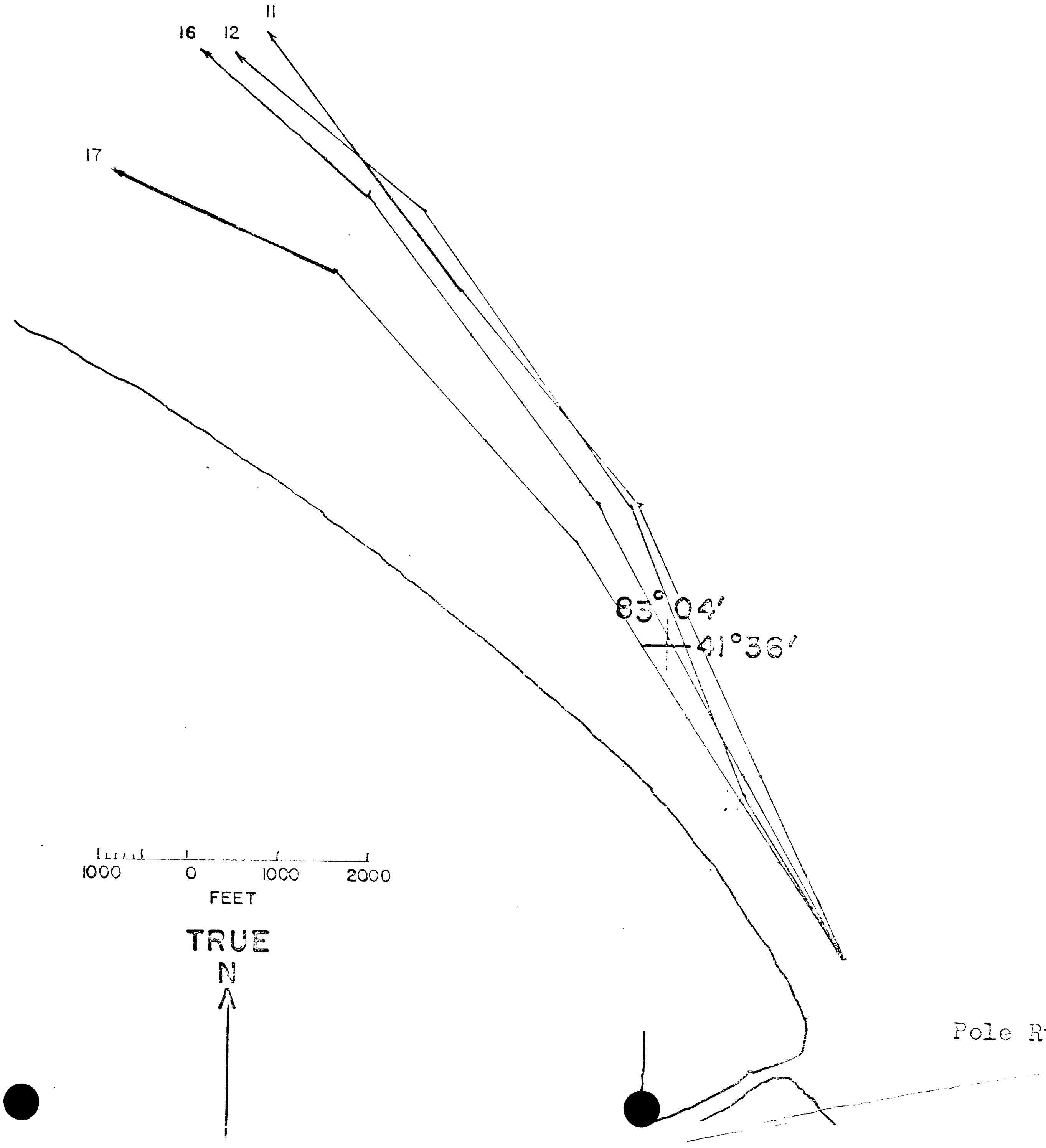


Figure 19
Pole Runs, 17 September 1968
Wind SSE

Table 21

Figure 20

September 18, 1968

Wind - SSE 150°

Table 21. September 18, 1968. Wind - SSE 150°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
16	5825	1.10	2	07	.53	150°	15	17
11	5950	1.13	2	20	.51	"	"	"
17	5500	1.04	2	26	.46	"	"	"
12	5650	1.07	2	35	.46	"	"	"

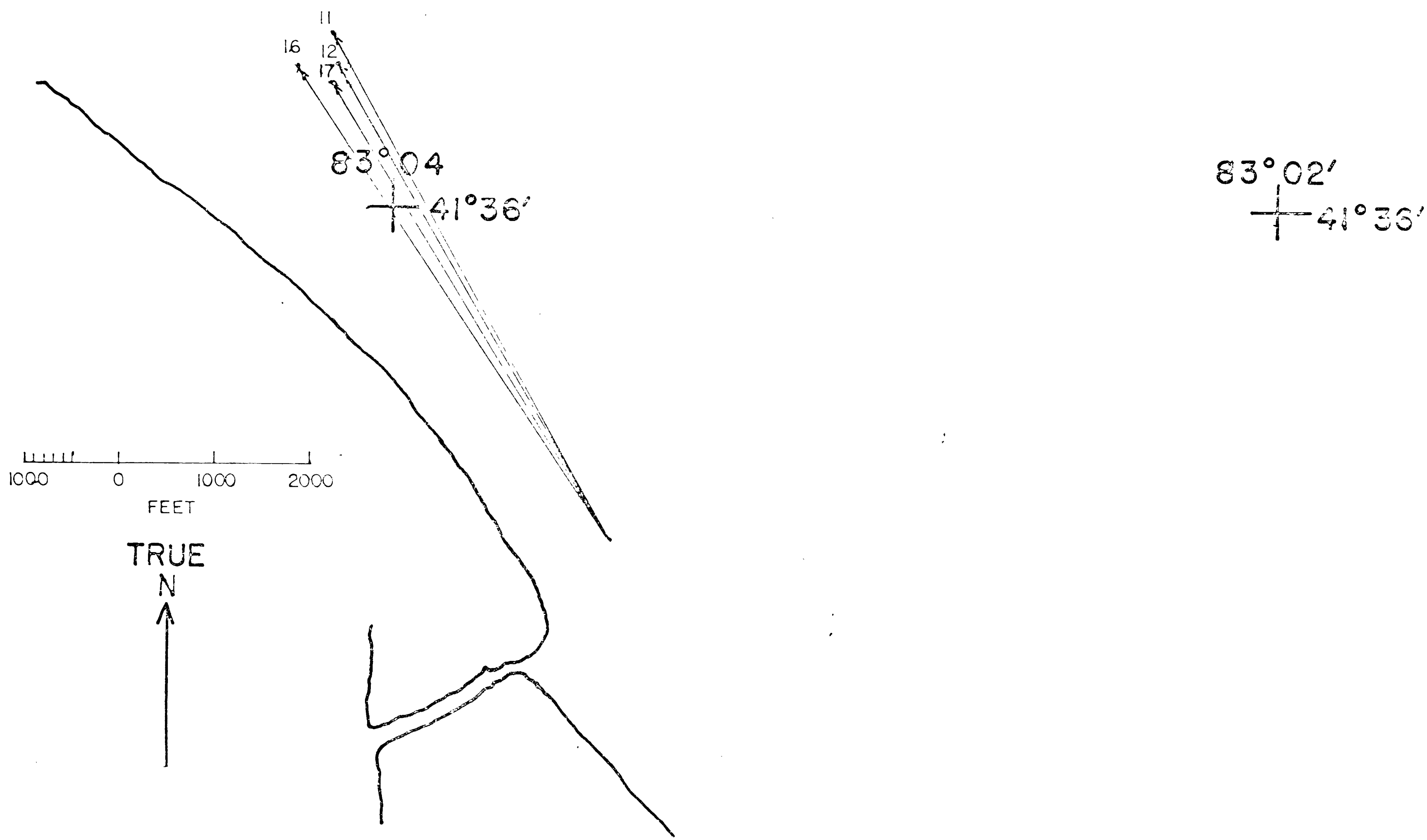


Figure 20. Pole Runs, [illegible] September 1968. Wind SSE.

DYE DILUTION STUDIES IN THE LOCUST POINT REGION

Our in situ studies of natural dilution rate in the alongshore water off the plant site used the red fluorescent dye, Rhodamine B. Stock dye in a 40% solution in acetic acid was used. It has a small negative buoyancy and requires dilution with an alcohol to become neutrally buoyant. Our dye sets consisted of one quart of the dye stock diluted with six quarts of methanol antifreeze. Concentration at setting was taken to be 6%. Dilutions were made in a plastic garbage can and introduced by gently lowering the can into the water until the dye floated out. After an interval to allow surface tension effects caused by the alcohol to die away, the initial measurement of dye concentration was made by slowly coasting the boat through the visibly-heaviest part of the dye patch. Slow coasting with the screw stopped allowed the boat to pass through the dye with little if any artificial mixing. Error from rapid spreading due to the surface tension effect of the alcohol has been compensated in the calculations.

Measurements of dye concentration were made with the ultraviolet fluorometer of Noble and Ayers (Limnology and Oceanography, Vol. 6, No. 4, 1961). In this instrument the fluorescence of the dye under ultraviolet light is measured photoelectrically and converted by calibration curve to concentration of dye. Colored water of the dye patch was pumped continuously through the fluorometer during each pass through the patch. Only the highest concentration noted during each pass was recorded and used in dilution computations, to obtain the most conservative dilution figures.

The stations for setting of the dye patches were in 4-6 feet of water, between 200 ft and 1000 ft offshore from the plant outfall. We have no reason to think that dilution figures obtained off other parts of the plant property would be significantly different from those presented here (Table 22).

In Table 22 the incremental dilution between two successive passes through

a dye patch was obtained by dividing the earlier dye concentration by the later. Each initial incremental dilution was severely rounded off to compensate for surface tension effects of the alcohol. Cumulative dilution was obtained by progressive multiplication of the incremental dilutions. After each multiplication the product was rounded to the nearest whole number before the next multiplication.

In the dye dilution experiments deliberate effort was exerted to run experiments on the calmest days possible, for low wind and minimum wave action produce least mixing and dilution, hence giving "worst condition" figures for dilution. Effort was also directed to obtaining observations under winds from as many directions as possible.

Successful dilution experiments were run on 6, 10, 12, 16, 17 and 18 September.

The alongshore current direction shown by the dye patch observed on September 12 (Table 19, and Fig. 18) is reported in the section on local currents. All the dye dilution data are summarized in Table 22.

On the basis of the data available, there appears to be a reasonable dilution rate inherent in the natural regimen of alongshore currents. The natural regimen will, however, be modified by the current created by the flow of plant effluent.

Table 22. Results of Dye Dilution Experiments.

Time Since Set	Dye Concentration	Incremental Dilution	Cumulative Dilution
6 Sept. 1968	Wind WSW 9-12 mph	Set at regular station	
Set	6×10^{-2}		
		7000X	
1 hr. 15 min.	8.4×10^{-6}		7000X
		2.8X	
1 hr. 38 min.	3.0×10^{-6}		20000X
		1.3X	
2 hr. 01 min.	2.3×10^{-6}		26000X
		1.9X	
3 hr. 05 min.	1.2×10^{-6}		49000X
		4.0X	
3 hr. 31 min.	3.0×10^{-7}		197000X
10 Sept. 1968	Wind SW 7-9 mph	Set at regular station	
Set	6×10^{-2}		
		1500X	
1 hr. 18 min.	3.0×10^{-5}		1500X
		3.6X	
3 hr. 15 min.	8.4×10^{-6}		3400X
		2.7X	
4 hr. 08 min.	3.1×10^{-6}		10000X
		2.6X	
4 hr. 40 min.	1.2×10^{-6}		26000X
12 Sept. 1968	Wind NW 5-7 mph	Set at regular station	
Set	6×10^{-2}		
		20000X	
1 hr. 21 min.	2.9×10^{-6}		20000X
		1.1X	
1 hr. 59 min.	2.8×10^{-6}		22000X
		2.6X	
2 hr. 42 min.	1.1×10^{-6}		57000X
		1.0X	
3 hr. 27 min.	1.1×10^{-6}		57000X
16 Sept. 1968	Wind ENE 12 mph	Set at regular station	
Set	6×10^{-2}		
		10000X	
1 hr. 01 min.	5.5×10^{-6}		10000X
		2.4X	
1 hr. 28 min.	2.3×10^{-6}		24000X
		2.1X	
1 hr. 58 min.	1.1×10^{-6}		50000X
		1.0X	
2 hr. 22 min.	1.1×10^{-6}		50000X

Table 22. (Continued)

Time Since Set	Dye Concentration	Incremental Dilution	Cumulative Dilution
17 Sept. 1968	Wind SSE 12 mph	Set at regular station	
Set	6×10^{-2}		
		10000X	
1 hr. 05 min.	5.0×10^{-6}		10000X
		2.3X	
1 hr. 43 min.	2.2×10^{-6}		23000X
		2.0X	
2 hr. 21 min.	1.1×10^{-6}		46000X
		4.8X	
2 hr. 51 min.	2.3×10^{-7}		140000X
18 Sept. 1968	Wind SSE 17 mph	Set at regular station	
Set	6×10^{-2}		
		11000X	
1 hr. 00 min.	5.2×10^{-6}		11000X
		2.2X	
1 hr. 30 min.	2.4×10^{-6}		24000X
		1.5X	
2 hr. 00 min.	1.6×10^{-6}		36000X
		2.3X	
2 hr. 54 min.	7.2×10^{-7}		82000X
		1.6X	
3 hr. 33 min.	4.6×10^{-7}		130000X

The studies reported above were designed to measure the present-day ability of the Locust Point area to dilute conservative material batch-released in the absence of the plant's plume of effluent warmed water.

They underestimate the dilution conditions that will exist for batch releases during the presence of a warm-water plume. Diluting lake-water will be entrained into the plume at its source. The released material will travel outward through the floating plume until, along the plume perimeter, cooling breaks down the temperature-induced density gradient and the released material can "fall off the edge" of the plume into the ambient lake water along an extensive line rather than at a point source.

COMPUTATIONS FOR A CONTINUOUS POINT-SOURCE RELEASE

This section consists of computations which were hired, because of our unfamiliarity with the model used. They were made by Dr. Joseph C-K. Huang, formerly of the University of Michigan, who is now with Scripps Institution of Oceanography at La Jolla, California. Because we cannot do so, Dr. Huang will answer questions stemming from this section. He should be addressed directly.

Per our instructions Dr. Huang has computed for that possibly unlikely case (see Figures 16 and 17) wherein a northwest wind was to hold the plant plume tightly against shore from Locust Point to well beyond the Camp Perry water intake.

Dr. Huang's results are presented verbatim below.

Estimation for Concentration Distributions for Conservative Material Released from a Continuous Point Source on the West Basin of Lake Erie

Joseph C-K. Huang

Most mathematical models describing the distribution of conservative material in a plume emanating from a continuous fixed source in the atmosphere or ocean are based on the assumptions that the turbulent field is homogeneous and stationary. The theoretical steady-plume models are deduced from the super-position of an infinite number of patch distributions in the presence of a mean current. If the flow field has a detectable mean velocity the diffusion in the direction of the current can be ignored. Furthermore, if the material distribution within any individual disk-element in the plume is assumed Gaussian, which is in general approximately the case, then the concentration at any point in a plume can be estimated by Gifford's (1959) two-dimensional model. In the lake, the mean concentration at any point

downstream from the continuous point source is given by

$$\bar{C}\ (x,\ y,\ z) = \frac{Q}{\pi\left(\bar{\sigma}_y^{2}\,\bar{\sigma}_z^{2}\right)^{1/2}\bar{U}}\ \mathrm{Exp}\ -\left[\frac{y^2}{2\bar{\sigma}_y^{2}} + \frac{z^2}{2\bar{\sigma}_z^{2}}\right], \tag{1}$$

where x, y, z are coordinates, x is in the direction of mean current, y is horizontal and perpendicular to the current direction, z is vertical; Q is the steady rate of discharge of conservative material from a point source in units/sec; $\bar{\sigma}^2$'s are the coordinate variances of the material distribution in cm^2; $\bar{U}$ is the mean current speed in cm/sec. Note that the above diffusion model is anisotropic.

The peak concentration on the surface of the lake is

$$\bar{C}_{max}(x) = \frac{Q}{\pi\left(\bar{\sigma}_y^{2}\bar{\sigma}_z^{2}\right)^{1/2}\bar{U}} \tag{2}$$

In a stationary homogeneous turbulent field, after a long period of time the diffusivity is considered to approach asymptotically a constant.

Csanady (1964) and Okubo and Farlow (1967) studied the turbulent diffusion in the West Basin of Lake Erie and have shown the effective lateral eddy diffusivity is about 10 cm /sec to 6 x 10 cm /sec and the vertical eddy diffusivity is about 1 - 10 cm /sec. Knowing the mean velocity of the current and the longitudional distance from the source, the mean coordinate variances can be estimated from

$$\bar{\sigma}^2 = \frac{2\ Kx}{\bar{U}} \tag{3}$$

where K is the diffusivity.

During the summer of 1968, we ran patches of Rhodamine B dye near Locust Point in Lake Erie. At the same time the mean currents were measured by surface drogues. The peak concentrations of the dye patch as a function of

time (or distance) were recorded from the fluorometer readings. The mean concentration distribution across the patch is approximately Gaussian.

As we are more interested in the concentration distribution of the conservation material in the effluent under the worst conditions, that is diffusion under an along-shore slow current, the lowest observed mean current about 10 cm/sec along the lake shore is used in this study.

The lower limit of coordinate variances for the continuous point source are taken from the variances calculated by equation (3) of the dye patch study with a lower limit value of diffusivity. Equivalently the concentrations predicted by equation (1) using the dye patch variances are the upper limit of the material concentration distributions.

Conservatively we are using the following data for the calculation of the point source concentration distributions:

$$Q = 1 \text{ unit/sec}$$

$$\overline{U} = 10 \text{ cm/sec}$$

$$Ky = 10^3 \text{ cm}^2\text{/sec}$$

$$Kz = 1 \text{ cm}^2\text{/sec}$$

Then from equation (3), the variances are

$$= 2 \times 10^2 X,$$

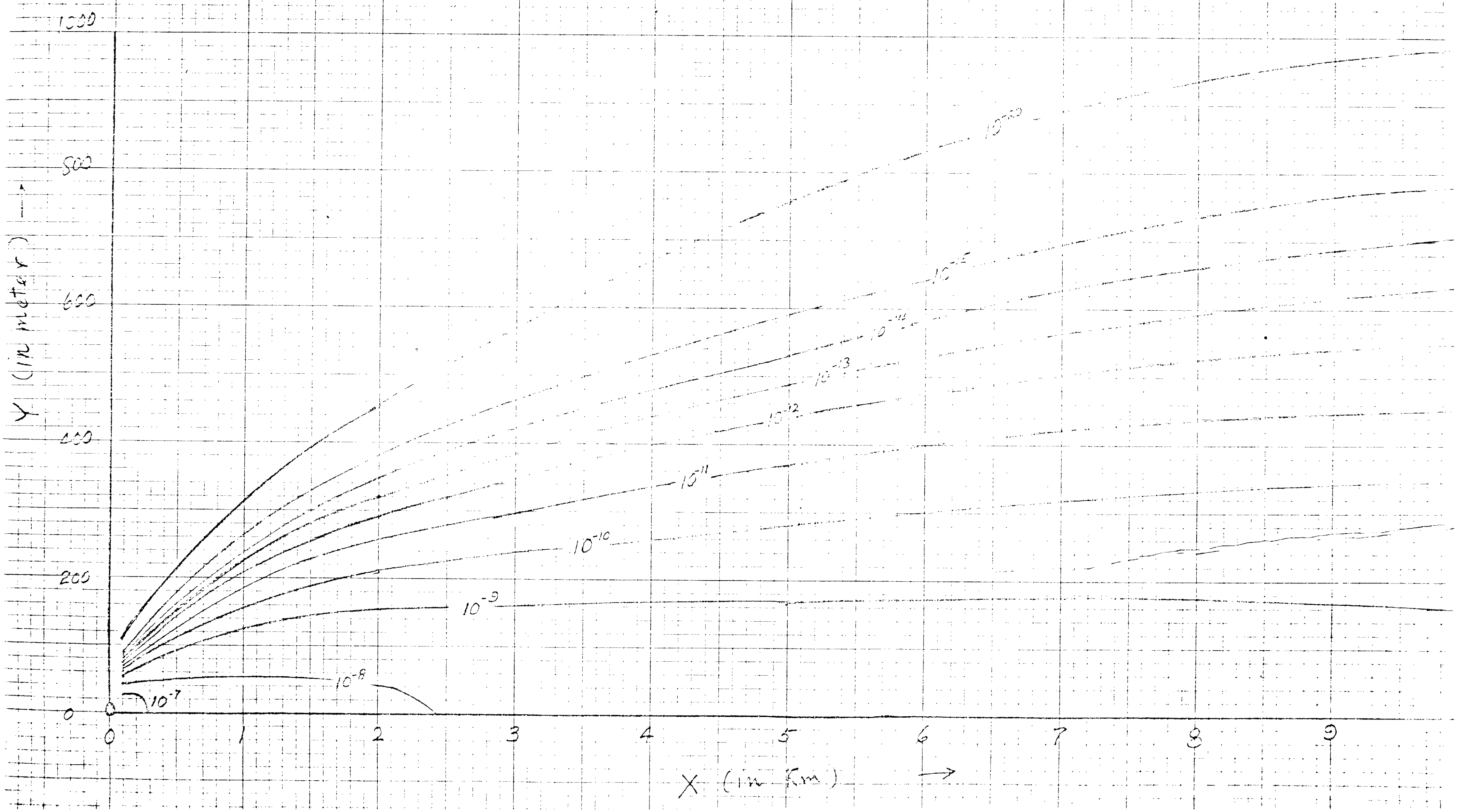
$$= 0.2 X.$$

The surface concentration distribution is plotted as shown in Figure 21. The concentrations along the beach (maximum conc.) and 100 m. away from the beach for each successive 1 Km downstream are listed in Table 23.

In treating the large scale diffusion phenomena, such as in this case with a large volume of discharged effluents from the power plant, it is more realistic to use the two-dimensional volume source model. In the volume source equation the variances at the origin is an essential parameter in

Fig. 1

Estimated Concentration Distributions From a Point Source



describing the concentration distributions. Since we have no similar survey to estimate the original variances of the volume source effluent, we cannot but use the point source equation which results in higher concentration distributions than the volume source (Foxworthy, *et al.* 1966). Note that the point source equation is not valid at the origin.

Due to our conservative estimation, using the lower limit of variance and the high concentration-predicting equation, the concentration distribution shown in Figure 21 is higher than that expected in the realistic situation in the lake away from the source.

Table 23. Surface concentration distribution along the beach and 100 meters away from the beach in the downstream direction from a unit/sec continuous point source.

Distance, X in Km	Conc. along beach	Conc. 100m. away from the beach
1/10	2.5×10^{-7}	3.5×10^{-17}
1	2.5×10^{-8}	2.1×10^{-9}
2	1.3×10^{-8}	3.6×10^{-9}
3	8.4×10^{-9}	3.6×10^{-9}
4	6.3×10^{-9}	3.4×10^{-9}
5	5.0×10^{-9}	3.1×10^{-9}
6	4.2×10^{-9}	2.8×10^{-9}
7	3.6×10^{-9}	2.5×10^{-9}
8	3.1×10^{-9}	2.3×10^{-9}
9	2.8×10^{-9}	2.1×10^{-9}
10	2.5×10^{-9}	2.0×10^{-9}

References

1. Csanady, G. T., Turbulence and Diffusion in the Great Lakes, Publ. No. 11, Great Lakes Research Division, University of Michigan, 326 (1964).

2. Foxworthy, J. E., R. B. Tibby, and G. M. Barsom, Dispersion of a Surface Waste Field in the Sea, Journal of Water Pollution Control Federation, Vol. 38, No. 7, 1170 (1966).

3. Gifford, F., Statistical Properties of a Fluctuating Plume Dispersion Model, Adv. Geophys., y, 117 (1959).

4. Okubo, A. and J. S. Tarlow, Analysis of Some Great Lakes Drogue Studies, Proc. 10th Conf. on Great Lakes Research, 299, (1967).

HYDROLOGICAL SURVEYS FOR THE LOCUST POINT POWER PLANT

PART III. PRELIMINARY BIOLOGICAL, FISHERIES, AND RADIOLOGICAL STUDIES

John C. Ayers
Robert F. Anderson
Norbert W. O'Hara
Dean E. Arnold
Charles C. Kidd

Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

January 16, 1970

This report covers those biological and radiological studies that have been completed to date. Additional biological and chemical analyses are still in progress and will be reported when they reach completion.

The materials reported here are:

1. Locust Point
   Phytoplankton, May 1969
   Zooplankton, May 1969, October 1969
   Benthos, May 1969, October 1969

2. Enrico Fermi
   Phytoplankton, June 1969
   Zooplankton, June 1969
   Benthos, June 1969

3. Locust Point
   Preliminary assessment of fish data

4. Locust Point, Big Rock, Fermi
   Studies on radionuclide uptakes by parts of the food chain

Still being processed are the phytoplankton samples from the Locust Point survey of October. Still to be processed are bulk samples of phytoplankton, zooplankton, and benthos; these will be analysed for the stable isotopes of metals to be expected in radwaste. Heavy pressure on the analytical equipment makes it unlikely that these analyses can be carried out before March.

The three surveys here reported were carried out to investigate biological conditions at Locust Point and to give comparison data from the region of the Enrico Fermi plant at Lagoona Beach in shallow northwest Lake Erie.

Station designations were arbitrarily chosen so that they showed the survey involved. Stations bearing an LPP (Locust Point Power) indicate the May 1969 coverage of the Locust Point region. Stations labelled with PL (Point Locust) mean the October 1969 coverage of Locust Point environs. Stations headed FP (Fermi Power) designate the June 1969 survey at Fermi.

The October Locust Point survey revisited the stations of the May survey, but the same station numbers were not retained. The station equivalency is as follows:

LPP-1 = PL-19	LPP-9 = PL-17
LPP-2 = PL-11	LPP-10 = PL-16
LPP-3 = PL-12	LPP-11 = PL-2
LPP-4 = PL-9	LPP-12 = PL-3
LPP-5 = PL-8	LPP-13 = PL-20
LPP-6 = PL-18	LPP-14 = PL-14
LPP-7 = PL-6	LPP-15 = PL-15
LPP-8 = PL-5	

The same station designations were used by C. Kidd in parts of the radiological studies which are reported below.

The surveys were in spring and fall to avoid the height of summer when emergent species of the benthos temporarily reduce the benthos by their nuptial flights. By fall the offspring of the mating flights are again back in the benthic community.

PRELIMINARY RESULTS

Although our studies of the data are far from complete, there are certain preliminary results that can be reported at this time.

May Phytoplankton, Locust Point:

Stations LPP-1, LPP-6, and LPP-9 immediately along the front of the plant property had relatively low phytoplankton counts, though lower ones occurred at stations off the mouth of the Toussaint River and off Camp Perry.

May and October Zooplankton, Locust Point:

In general, May zooplankton counts over the whole area tended to be higher and October counts tended to be low. As a rough index the sum of the numbers present in both months in the duplicated stations of both cruises has been used. When the catches are summed, the least total is 37.50 organisms per liter for Station LPP-6 (= PL-18); followed by 41.40 at Station LPP-9 (= PL-17); then

46.09 for LPP-3 (= PL-12); with 69.39 at LPP-15 (= PL-15); and 76.51 at LPP-1 (= PL-19); the remaining duplicated stations have substantially higher combined counts. Except for station 15, the low values are along the shore of the plant property.

May and October Benthos, Locust Point:

Benthos in the Locust Point region are sparse compared to areas further offshore. This is attributable to wave action which winnows out finer sediments and detrital food materials.

In the inshore stations most apt to be effected by the plant discharge (LPP-1, 6, 9, 13, 2, and 3; PL-19, 10, 18, 7, 17 and 4) the benthos are exceedingly sparse.

June Phytoplankton, Fermi:

In summary the phytoplankton types off the Fermi plant were about the same as those off Locust Point. There were some additional genera and species at some of the Fermi stations, which may be related to the direct influence of the Detroit River. Phytoplankton cell counts per liter were consistently lower than at Locust Point, probably reflecting the greater degree of pollution in the Detroit area.

June Zooplankton, Fermi:

Except at station FP-1 which is in Brest Bay about 6 miles from Fermi, the zooplankton of the area were very rare. Again, this appears to be a reflection of pollution in the area.

June Benthos, Fermi:

At Fermi only the Sphaeriids (finger nail clams) and the pollution-tolerant oligochaetes were more numerous than at Locust Point. The clean-water loving amphipods were practically absent from the Fermi region.

SUMMARY STATEMENT

Preliminary assessments of the biological data now worked up show that the inshore waters at Locust Point are, compared to regions further offshore, a sort of "biological desert" only sparsely inhabited by plankton and benthos. Such is also true at other plant sites we have studied.

Preliminary examination of the fishery data available, suggests that the sampling stations used are too far from Locust Point and too far offshore to be adequately representative of fish populations close to the Point. This conclusion is preliminary and may be modified by further study. It may be significant that local fishermen reduce or cease their operations at Locust Point during the height of the summer "because the fish leave the area" (Ohio Division of Wildlife).

Present evidence, though incomplete, suggests that in the critical peak-of-summer condition there are but few biological organisms present to be damaged in the area of the plant outfall where the greatest of waste heat will exist.

Comparative studies in the Fermi region are disappointing because they predominately indicate the polluted nature of the area.

In radiological studies presently completed the amphipod, Pontoporeia affinis, shows a greater affinity for zinc-65 than for cerium-144, manganese-54, cesium-137, zirconium-95, ruthenium-106, or strontium-90. Uptake of zinc and strontium was enhanced somewhat when the amphipod was cultured with sediment in the aquarium.

Lake Erie chironomids (tendepedidae) and oligochaetes when similarly cultured with sediments also showed their affinities for zinc-65 to be greater than for manganese-54, cesium-137, or strontium-85.

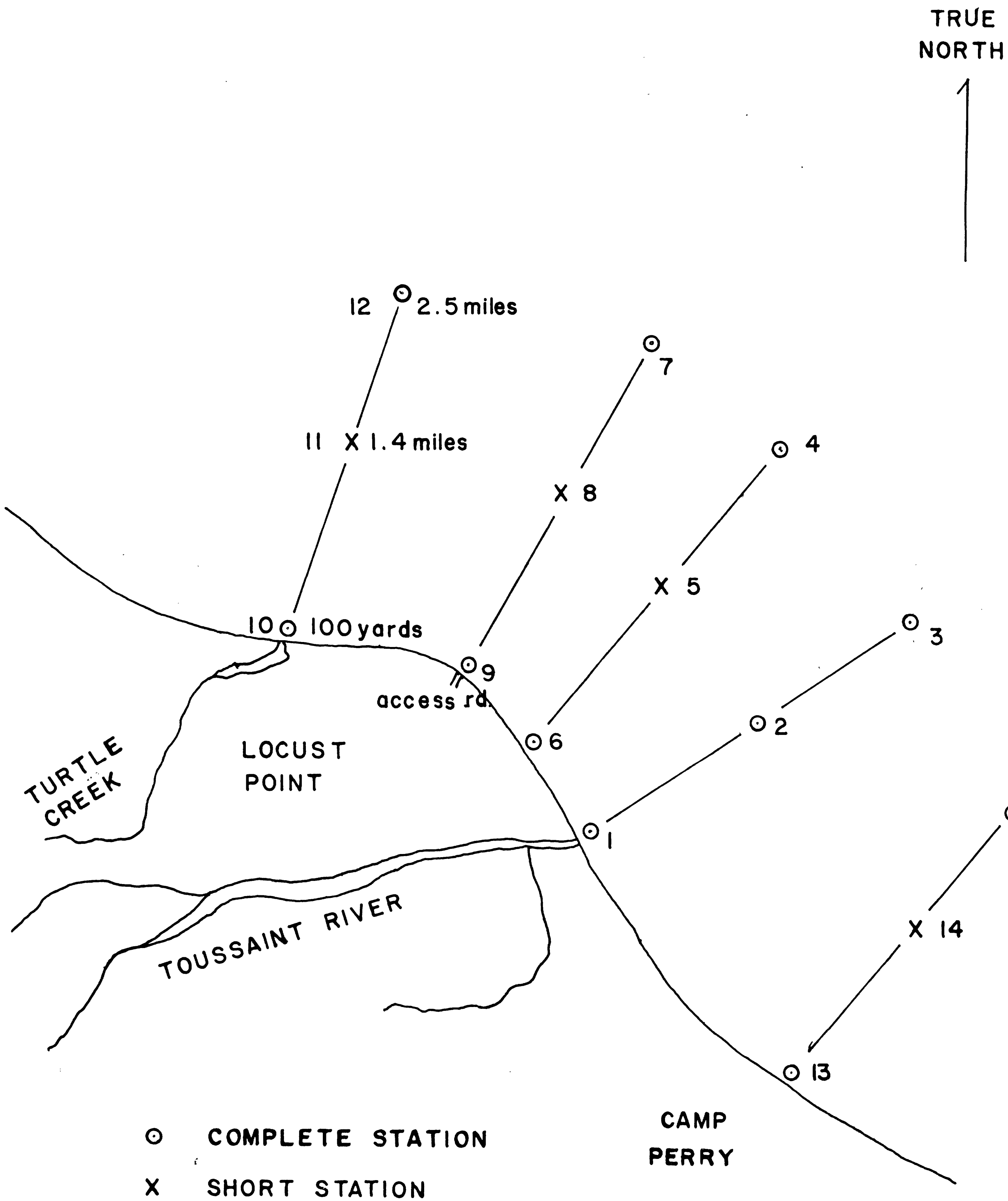
Lake Erie clams similarly cultured had soft-tissue affinities for cesium-137 greater than for zinc, manganese, or strontium. Clam shell appeared to concentrate both cesium and manganese more readily than the others.

Despite the fact that Fermi has operated nuclear there are no significant differences in gross beta activity or cesium-137 activity between Fermi and Locust Point sediments.

Amphipods captured in the vicinity of the Big Rock reactor showed small increases in gross gamma and gross beta activities in a limited area in front of the plant.

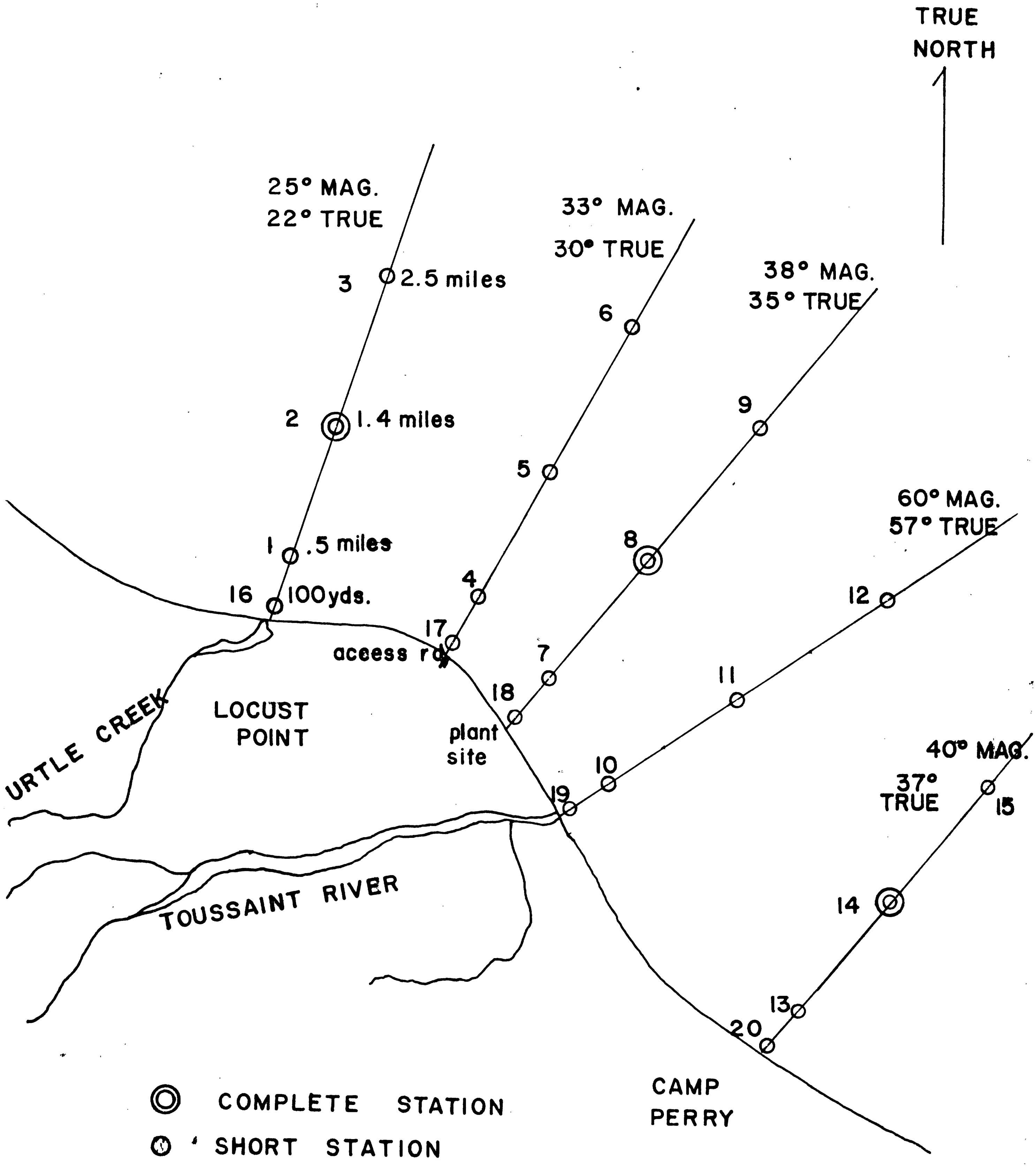
STATION MAP OF LOCUST POINT PROJECT

MAY 1969, SAMPLING



STATION MAP OF LOCUST POINT

OCTOBER 1969, SAMPLING



Phytoplankton Population
Locust Point, 15-16 May 1969

Diatoms
- Diatoma tenuis v. elongata
- Melosira binderana
- Melosira granulata
- Synedra ulna
- Synedra acus
- Fragilaria intermedia
- Fragilaria capucina
- Fragilaria crotonensis
- Asterionella formosa
- Cyclotella spp
- Navicula spp
- Tabellaria fenestrata
- Surirella spp
- Nitzschia spp
- Stephanodiscus spp
- Cymbella spp
- Gomphonema spp

Greens
- Ulothrix spp
- Pediastrum duplex
- Scenedesmus abundans
- Scenedesmus quadricauda
- Dictyosphaerium pulchellum
- Ankistrodesmus spp
- Ankistrodesmus falcatus
- Scenedesmus spp
- Micractinium pusillium
- Oocystis solitaria
- Lagerheimia longiseta
- Golenkinia radiata
- Actinastrum Hantzschii
- Closteriopsis longissima

Blue Greens
- Oscillatoria spp

Phytoplankton

Station LPP-1, Locust Point
15 May 1969

Organism	No. of Colonies	Cell per Liter
:illatoria spp		3,747
ıgilaria crotonensis	1,874	51,524
:istrodesmus falcatus		937
ıtoma tenuis v. elongata	42,156	287,598
.osira binderana	66,513	526,482
;erionella formosa	6,558	49,651
ıgilaria capucina	49,651	2,243,636
:lotella spp		7,494
'icula spp		937
.ystis solitaria		937
:nedesmus quadricauda		937
ıedra ulna		937
,ellaria fenestrata	4,684	30,914
'irella spp		937

Phytoplankton

Station LPP-2, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
iedra ulna		17,666
iedra acus		6,625
bellaria fenestrata	2,208	15,458
liastrum duplex		2,208
.osira binderana & M. granulata combined	516,742	4,891,385
itoma tenuis v. elongata	99,374	1,355,896
erionella formosa	24,291	249,538
igilaria crotonensis	4,417	117,040
igilaria capucina	105,998	5,284,462
:lotella		6,625
enedesmus abundans		2,208
cystis solitaria		2,208
cillatoria spp		2,208

Phytoplankton

Station LPP-3, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Diatoma tenuis v. elongata	47,917	242,675
Oscillatoria spp		1,546
Ulothrix spp		1,546
Melosira binderana	61,828	930,512
Synedra acus		4,637
Synedra ulna		6,183
Fragillaria intermedia	17,003	630,646
Fragillaria capucina	4,637	98,925

Phytoplankton

Station LPP-4, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		13,138
Tabellaria fenestrata	10,049	57,202
Diatoma tenuis v. elongata	66,478	672,510
Melosira binderana & M. granulata combined	202,526	937,649
Fragilaria crotonensis	1,546	58,748
Asterionella formosa	17,006	135,275
Fragilaria capucina	85,030	3,237,324
Lagerheimia longiseta		773
Golenkinia radiata		773
Cyclotella spp		3,865
Oscillatoria spp		2,319
Dictyosphaerium pulchellum		1,546
Scenedesmus quadricauda		773
Synedra acus		2,319

Phytoplankton

Station LPP-6, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis	2,132	14,924
Surirella spp		1,066
Synedra ulna		6,396
Synedra acus		1,066
Dictyosphaerium pulchellum		1,066
Ankistrodesmus spp		1,066
Oscillatoria spp		2,132
Tabellaria fenestrata	7,462	33,046
Diatoma tenuis v. elongata	74,620	380,562
Melosira binderana & M. granulata combined	105,534	891,176
Fragilaria capucina	49,036	1,557,426
Scenedesmus abundans		1,066
Closteriopsis longissima		1,066

Phytoplankton

Station LPP-7, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		4,986
Surirella sp		997
Oocystis solitaria		997
Melosira binderana & M. granulata combined	101,714	622,253
Diatoma tenuis v. elongata	50,857	283,205
Asterionella formosa	9,972	81,770
Tabellaria fenestrata	3,989	12,964
Fragilaria capucina	49,860	1,471,867
Micractinium pusillum		1,994
Oscillatoria spp		1,994

Phytoplankton

Station LPP-9, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp		5,888
Micractinium pusillum		1,472
Scenedesmus quadricauda		1,472
Synedra ulna		8,832
Cyclotella spp		10,304
Gomphonema sp		1,472
Stephanodiscus spp		2,944
Synedra acus		7,360
Melosira binderana & M. granulata combined	113,344	1,149,632
Asterionella formosa	5,888	27,968
Tabellaria fenestrata	1,472	8,832
Diatoma tenuis v. elongata	75,072	450,432
Fragilaria crotonensis	2,944	79,488
Fragilaria capucina	41,216	585,856

Phytoplankton

Station LPP-10, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis	6,183	74,191
Synedra acus		15,457
Synedra ulna		6,183
Oscillatoria spp		15,457
Melosira binderana & M. granulata combined	420,417	3,159,309
Fragilaria capucina	108,196	2,550,323
Scenedesmus spp		3,091
Cyclotella spp		9,274
Ankistrodesmus falcatus		3,091
Nitzschia spp		9,274
Diatoma tenuis v. elongata	272,034	1,415,815
Asterionella formosa	12,365	83,465
Tabellaria fenestrata	6,183	27,823

Phytoplankton

Station LPP-12, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		4,314
Oscillatoria spp		6,470
Actinastrum Hantzschii		2,157
Diatoma tenuis v. elongata	42,058	208,131
Melosira binderana & M. granulata combined	73,331	815,270
Asterionella formosa	4,314	38,822
Tabellaria fenestrata	5,392	20,490
Fragilaria capucina	21,570	628,707
Scenedesmus abundans		1,078
Cyclotella		3,235

Phytoplankton

Station LPP-13, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Scenedesmus quadricauda		1,546
Oscillatoria spp		12,368
Stephanodiscus spp		9,276
Synedra acus		10,822
Dictyosphaerium pulchellum		6,184
Ankistrodesmus spp		3,092
Actinastrum Hantzschii		3,092
Cyclotella spp		9,276
Micractinium pusillum		3,092
Synedra ulna		6,184
Tabellaria fenestrata	6,184	30,920
Diatoma tenuis v. elongata	123,680	1,004,900
Melosira binderana & M. granulata combined	536,462	5,468,202
Fragilaria capucina	40,196	1,456,332
Cymbella sp		1,546
Asterionella formosa	4,638	30,920

Phytoplankton

Station LPP-15, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp		6,624
Ankistrodesmus spp		2,208
Navicula sp		1,104
Synedra acus		4,416
Fragilaria crotonensis	1,104	37,536
Melosira binderana & M. granulata combined	59,616	623,760
Diatoma tenuis v. elongata	44,160	195,408
Tabellaria fenestrata	9,936	40,848
Asterionella formosa	1,104	11,040
Fragilaria capucina	28,704	1,065,360
Synedra ulna		2,208
Cyclotella spp		6,624
Closteriopsis longissima		1,104

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	LPP-1 5/15/69	PL-19 (=LPP-1) 10/29/69	LPP-3 5/15/69	PL-12 (=LPP-3) 10/21/69	LPP-4 5/15/69	PL-9 (=LPP-4) 10/21/69	LPP-6 5/15/69	PL-18 (=LPP-6) 10/29/69	LPP-7 5/15/69	PL-6 (=LPP-7) 10/24/69
CALANOID COPEPODS:										
Diaptomus sp.	3.82	0.71	2.76	0.40	4.21	0.48	1.37		7.43	0.15
Eurytemora affinis		0.59		0.20				0.13		0.46
Others										
CYCLOPOID COPEPODS	29.72	3.18	14.60	3.69	33.97	4.96	10.88	0.47	77.86	2.39
ROTIFERS:										
Asplanchna sp.	3.47	0.12	1.75	0.30	1.81	0.48	2.05		5.99	
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva	15.62	1.06	5.51	0.66	34.66	0.31	14.47	0.13	46.33	0.25
Other Daphnia	0.20	0.12	0.13	0.07	0.08		0.06		0.20	
Bosmina sp.	3.20	13.55	4.24	11.23	4.09	10.70	3.76	3.48	5.15	4.62
Chydorus sphaericus	0.13		0.13		0.04			0.07		
Ceriodaphnia reticulata										
Leptodora kindtii	0.27	0.12	0.35	0.03	0.84	0.04	0.63		0.98	
Sida crystallina										
OTHER GROUPS: (Ostracods unless otherwise noted)	0.51	0.12	0.04		0.04					Hydra 0.05
REMARKS:								Very dirty sample		

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	LPP-9 6/15/69	PL-17 (=LPP-9) 10/29/69	LPP-10 5/16/69	PL-16 (=LPP-10) 10/28/69	LPP-12 5/16/69	PL-3 (=LPP-12) 10/24/69	LPP-13 5/16/69	PL-20 (=LPP-13) 10/29/69	LPP-15 5/16/69	PL-15 (=LPP-15) 10/27/69
CALANOID COPEPODS:										
Diaptomus sp.	1.65		3.76	0.62	6.51	0.04	28.77	0.15	5.63	0.37
Eurytemora affinis		0.71		1.87		0.32		0.53		0.51
Others										
CYCLOPOID COPEPODS	9.97	0.59	42.34	3.50	56.55	1.56	132.80	2.05	53.53	1.11
ROTIFERS:										
Asplanchna sp.	1.24	0.12	12.62	0.19	1.11		0.23	0.30	1.83	0.03
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva	8.16	0.82	22.87	2.74	12.30	0.28	4.49	0.38	1.90	0.10
Other Daphnia					0.08				0.10	
Bosmina sp.	2.95	13.67	8.01	30.53	2.87	6.94	19.79	14.94	2.47	1.01
Chydorus sphaericus	0.03									0.03
Ceriodaphnia reticulata			0.06					0.15		
Leptodora kindtii	1.49		3.46	0.05	0.34		0.12	0.15	0.07	0.03
Sida crystallina										
OTHER GROUPS:									0.67	
(Ostracods unless otherwise noted)										

REMARKS:

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	PL-1 fall only 10/24/69	PL-2 fall only 10/24/69	PL-4 fall only 10/24/69	PL-5 fall only 10/24/69	PL-7 fall only 10/21/69	PL-8 fall only 10/21/69	PL-10 fall only 10/21/69	PL-11 fall only 10/21/69	PL-13 fall only 10/20/69	PL-14 fall only 10/20/69
CALANOID COPEPODS:										
Diaptomus sp.	0.69	0.06	0.04		0.56	0.57	0.30	0.16	0.57	0.38
Eurytemora affinis		0.44	0.84	0.67	0.11	0.08		0.06	0.04	0.05
Others										
CYCLOPOID COPEPODS	2.71	0.25	1.52	0.28	7.89	2.62	3.28	0.94	2.53	2.10
ROTIFERS:										
Asplanchna sp.	0.13	0.06	0.11		0.11	0.11		0.28	0.26	0.14
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva		0.57	0.19	0.39	0.61	0.27	0.55	0.31	1.09	1.39
Other Daphnia										
Bosmina sp.	7.24	4.05	9.53	3.15	15.61	7.22	7.07	3.56	11.04	11.09
Chydorus sphaericus										
Ceriodaphnia reticulata										
Leptodora kindtii			0.08							
Diaphanosoma leuchtenbergianum	0.06									
OTHER GROUPS:										
(Ostracods unless otherwise noted)										

REMARKS:

LOCUST POINT POWER PROJECT

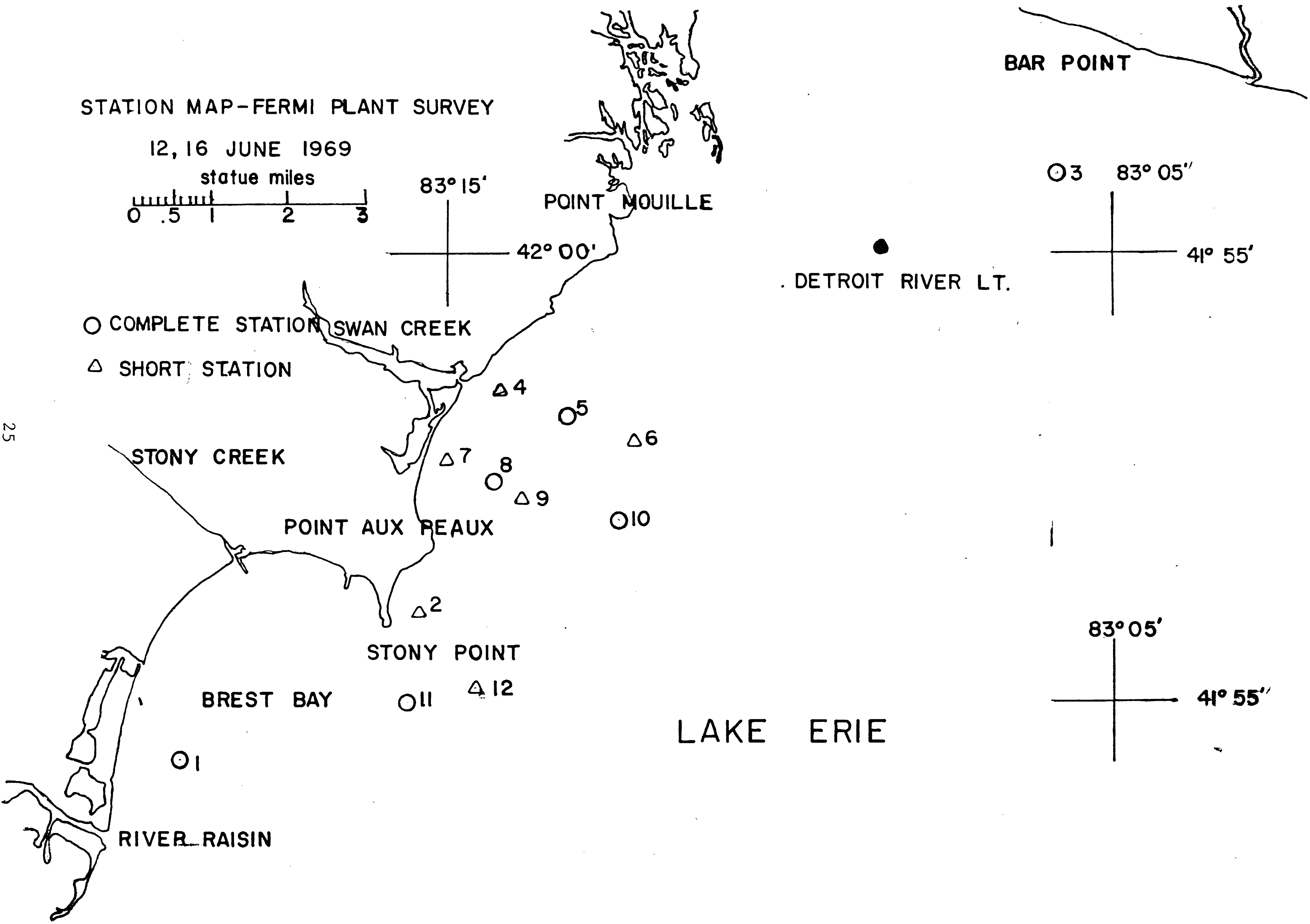
Benthos Data

Station Number	Date	Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other		Ratio: Amphi/Oligo
		Organisms per meter^2						
LLP-1	5/15/69	0	4877	17	965	Snail	52	0
-2	5/15/69	26	5364	26	1165	0		0.0048
-3	5/15/69	0	86	0	43	Snail shells		0
-4	5/15/69	8	1452	34	991	Daphnia	26	0.0059
-5	5/15/69	52	2269	34	565	Daphnia	17	0.0229
-6	5/15/69	0	26	0	78	Snail	17	0
						Cyclops	43	
						Copepod	8	
-7	5/15/69	26	2399	121	39	Cyclops	113	0.0108
						Daphnia	443	
						Snail	339	
-8	5/15/69	52	1217	17	286	Cyclops	43	0.0428
						Daphnia	34	
						Snail	782	
-9	5/15/69	17	165	0	199	Daphnia	43	0.1052
						Cyclops	252	
-10	5/16/69	26	121	0	234	0		0.2142
-11	5/16/69	34	808	8	452	Daphnia	8	0.0430
-12	5/16/69	26	26	8	982	Snails	26	1.0000
						Cyclops	130	
						Daphnia	956	
-13	5/16/69	0	113	0	191	Snail	8	0
						Daphnia	460	
						Cyclops	156	
-14	5/16/69	0	895	8	295	Cyclops	78	0
						Daphnia	60	
-15	5/16/69	0	686	8	1278	0		0

LOCUST POINT POWER PROJECT

Benthos Data

Station Number	Date	Organisms per meter^2						Ratio: Amphi/Oligo
		Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other		
P1-1	10/24/69	0	1139	0	348	Clam	9	0
-2	10/29/69	0	678	0	730	Leech Clam	9 9	0
-3	10/24/69	0	556	17	565	0		0
-4	10/24/69	0	3148	0	270	0		0
-5	10/24/69	0	956	17	565	0		0
-6	10/24/69	17	1026	17	539	Clam	17	0.0166
-7	10/21/69	9	522	0	70	0		0.0172
-8	10/21/69	35	1252	0	130	Leech	26	0.0280
-9	10/21/69	104	391	278	70	Leech	174	0.2660
-10	10/21/69	43	461	17	165	Leech	9	0.0933
-11	10/21/69	0	617	78	130	0		0
-12	10/21/69	400	130	96	52	Leech Clam	9 9	3.0769
-13	10/20/69	104	96	26	78	Leech	9	1.0833
-14	10/20/69	78	157	9	35	Leech	17	0.4968
-15	10/29/69	61	261	35	130	Leech	35	0.2337
-16	10/29/69	0	70	0	61	0		0
-17	10/29/69	0	0	0	0	0		0
-18	10/29/69	0	26	0	0	0		0
-19	10/29/69	17	96	35	87	0		0
-20	10/29/69	9	1530	0	78	0		0


STATION MAP-FERMI PLANT SURVEY
12, 16 JUNE 1969
statue miles
0 .5 1 2 3
○ COMPLETE STATION
△ SHORT STATION
83° 15'
42° 00'
POINT MOUILLE
SWAN CREEK
STONY CREEK
POINT AUX PEAUX
STONY POINT
BREST BAY
RIVER RAISIN
BAR POINT
○3
83° 05''
41° 55'
DETROIT RIVER LT.
83° 05'
41° 55''
LAKE ERIE
△4
○5
△6
△7
○8
△9
○10
△2
○11
△12
○1

Phytoplankton

Station FP-1, near Enrico Fermi
12 June 1969

Organism	No. of Colonies	Cells per Liter
Cyclotella spp		32,621
Oocystis spp		1,546
Actinastrum Hantzschii		6,184
Scenedesmus spp		6,802
Micractinium ? spp		6,493
Dictyosphaerium spp		2,010
Ankistrodesmus spp		1,237
Peridinium sp		618
Gomphosphaeria lacustris		155
Oscillatoria spp		7,421
Closteriopsis longissima		1,701
Melosira spp	1,546	9,121
Synedra sp		1,237
Asterionella formosa	155	618
Fragilaria pinnata	309	5,411
Diatoma tenuis v. elongata	155	618
Stephanodiscus sp		618
Coelastrum sp		773
Tetraedron sp		309
Coscinodiscus sp		155
Pediastrum sp		309
Closteridium sp		309
Navicula sp		309
Nitzschia sp		309

Phytoplankton

Station FP-3, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Dinobryon divergens	1,288	18,032
Oscillatoria spp		7,084
Synedra acus		27,048
Synedra ulna		17,388
Rhizosolenia eriensis		47,656
Nitzschia sp		644
Tabellaria fenestrata	22,540	155,848
Asterionella formosa	10,948	71,484
Diatoma tenuis v. elongata	15,456	94,024
Fragilaria capucina	4,508	144,900
Melosira binderana & M. granulata combined	1,932	12,880
Gloeocystis sp		2,576
Cyclotella spp		10,304
Micractinium sp		644

Phytoplankton

Station FP-5, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Oocystis sp		86
Diatoma spp	602	2,494
Tabellaria fenestrata	774	4,816
Melosira spp	258	2,322
Synedra spp		1,204
Fragilaria pinnata	344	7,224
Asterionella spp	258	1,290
Cyclotella sp		344

Phytoplankton

Station FP-8, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Stephanodiscus spp		883
Synedra acus		4,416
Synedra ulna		3,386
Cyclotella spp		7,949
Diatoma tenuis v. elongata	4,564	24,290
Nitzschia spp		1,030
Melosira binderana & M. granulata combined	12,366	92,889
Fragilaria pinnata	3,091	117,621
Fragilaria crotonensis	1,325	25,320
Navicula spp		442
Coelastrum sp		147
Oscillatoria spp		442
Rhizosolenia spp		442
Oocystis solitaria		147
Actinastrum Hantzschii		294
Cosmarium sp		294
Ankistrodesmus sp		147
Dinobryon sp		294
Tabellaria fenestrata	8,244	67,569
Asterionella formosa	3,091	23,406
Pediastrum duplex		442
Cymbella sp		147
Coscinodiscus sp		147

Phytoplankton

Station FP-10, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Diatoma tenuis v. elongata	6,901	37,801
Tabellaria fenestrata	6,283	83,327
Asterionella formosa	4,223	30,385
Oscillatoria spp		1,133
Rhizosolenia spp		1,030
Pediastrum sp		309
Stephanodiscus sp		515
Synedra spp		13,184
Melosira spp	7,210	48,925
Cyclotella spp		1,545
Fragilaria crotonensis & F. pinnata combined	5,562	194,876
Nitzschia spp		515
Dinobryon spp	1,236	12,875
Ankistrodesmus sp		206
Scenedesmus sp		103

Phytoplankton

Station FP-12, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Micractinium spp		10,626
Coelastrum sp		7,728
Asterionella formosa	7,728	51,198
Ankistrodesmus falcatus		2,898
Dictyosphaerium pulchellum		5,796
Cyclotella spp		176,778
Melosira spp	178,710	1,109,934
Diatoma tenuis v. elongata	11,592	90,804
Rhizosolenia eriensis	966	1,932
Pediastrum sp		7,728
Nitzschia sp		1,932
Actinastrum Hantzschii		15,456
Oscillatoria spp		163,254
Scenedesmus spp		29,946
Tabellaria fenestrata	22,218	118,818
Synedra spp		35,742
Fragilaria capucina	5,796	168,084
Fragilaria crotonensis	1,932	69,552
Oocystis sp		2,898
Navicula sp		966
Anabaena sp		966

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - ENRICO FERMI, LAKE ERIE (NO. ORG./LITER)

	FP-1 6/12/69	FP-3 6/16/69	FP-5 6/16/69	FP-8 6/16/69	FP-10 6/16/69	FP-12 6/16/69
CALANOID COPEPODS:						
Diaptomus sp.	0.53	0.41	0.10	0.13	0.21	0.07
Eurytemora affinis		0.05			0.04	
Others						
CYCLOPOID COPEPODS	122.01	0.51	0.24	1.00	0.08	11.28
ROTIFERS:						
Asplanchna sp.		0.66	0.29	0.63	1.48	0.07
(Others too small for this net)						
CLADOCERA:						
Daphnia retrocurva	0.75			0.04		2.38
Other Daphnia						0.10
Bosmina sp.	0.32	0.41	0.05	0.75	0.13	1.98
Chydorus sphaericus	0.53	0.31	0.19			0.07
Ceriodaphnia reticulata						0.07
Leptodora kindtii	0.11					0.10
Diaphanosoma leuchtenbergianum						
OTHER GROUPS:						
(Ostracods unless otherwise noted)						

REMARKS:

ENRICO FERMI POWER PLANT

Benthos Data

Station Number	Date	Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other		Ratio: Amphi/Oligo
		Organisms per meter^2						
FP-1	6/24/69	0	2964	0	1312	0		0
-2	6/29/69	0	4817	17	1043	0		0
-3	5/18/69	0	2060	1399	530	Egg Sac	156	
						Snail	321	0
-4	6/16/69	0	95	8	0	0		0
-5	6/25/69	0	1869	8	34	0		0
-6	6/20/69	0	5634	60	17	0		0
-7	7/1/69	8	69	17	8	0		0.125
-8	6/23/69	0	339	0	60	0		0
-9	6/16/69	0	1243	26	95	0		0
-10	6/16/69	0	4790	321	17	0		0
-11	6/25/69	0	921	460	90	Snail	26	0
						Leech	8	
-12	6/26/69	0	1225	43	52	0		0

FISH AND FISHERIES IN THE AREA OF THE PROPOSED LOCUST POINT POWER PLANT

Due to lack of time and equipment, data on the fish situation was not collected directly, but was obtained from various government reports and from interviews with fisheries biologists working in the area. The U. S. Bureau of Commercial Fisheries established an "index" station, known as Bono or No. 7, in 1959. Annual collections were made at this station until 1965 and are summarized in table 1. The station is located 8-1/2 miles northwest of Locust Point and is 2 miles offshore with a depth of 20 feet (figure 1). Unfortunately the bottom at the Bono station is mostly mud, whereas the bottom at the same distance and depth off Locust Point is sandy gravel (Herdendorf, 1968; Ayers and Anderson, 1969). This difference and the distance involved may cause significant differences in the relative abundance of various fish species at the two locations. Nevertheless, these data provide a convenient summary of the fish populations in the Locust Point area. Growth rate data, which would also be of interest in evaluating power plant effects, is available for only a few species and times. Since the fish populations of Lake Erie have been somewhat unstable over the last decade, and the USBCF data extends only through 1965, present relative abundance of the fish species may be somewhat different from that implied by table 1.

The Ohio Division of Wildlife fishery studies in western Lake Erie are concentrated on the walleye, which is the only remaining "high-value" (in the traditional sense) fish in the commercial catch, and which is in danger of population collapse (Arnold, 1969a; Regier, Applegate, and Ryder, 1969). They also have records from trap net and haul seine commercial fisheries near Locust Point but inasmuch as the fishermen specialize in one or two species and generally report only those fish selected for market, this data was not particularly useful for our purposes.

Approximately 14 major and 5 minor species of fish occur around Locust Point. The species composition is heavily in-

Table 1: Summary of USPCF index collections at Bono (#7) station
(Means of 2 10-minute hauls of 26' trawl, ½-inch mesh.)

Species	age group	June 1959	Aug. 1959	Oct. 1959	Aug. 1960	Aug. 1961	Aug. 1962	Aug. 1963	Aug. 1964	Aug. 1965
Yellow Perch	adult	26	15	3	6	3	4	48	97	73
	yearling	24		3	49		8	260	37	29
	young of year		195	144	109	519	162	104	25	205
Emerald Shiner	adult	76	89	78	3	55	55	1	52	
	yearling	139				986	47	1	92	2
	young of year				1			1		
Spottail Shiner	adult	6	23	61	48	17	4	21	22	3
	yearling	17		9		19	12	72	36	8
	young of year		14	67	97	56	2	29	66	246
Smelt	adult	1								
	yearling									
	young of year				1	66		9		1
Troutperch	adult	5	3	22	15		1	1	2	
	yearling	7				2	1	4	3	8
	young of year		3		22	7		9	38	22
Sheepshead	adult	1			6		1		3	10
	yearling	2				1			2	6
	young of year		1					1	3	71
Channel Catfish	adult				4	1			1	1
	yearling	1								1
	young of year									
Walleye	adult				1					
	yearling									
	young of year			1		2			1	
Carp	adult				1	4				
	yearling			1						1
	young of year									1
Alewife	adult									
	yearling									
	young of year			10		80	265	24	56	3
White Bass	adult									
	yearling									
	young of year		15	6	19	153	165	121	17	10
Others		3	1	1	1		5	21	20	2

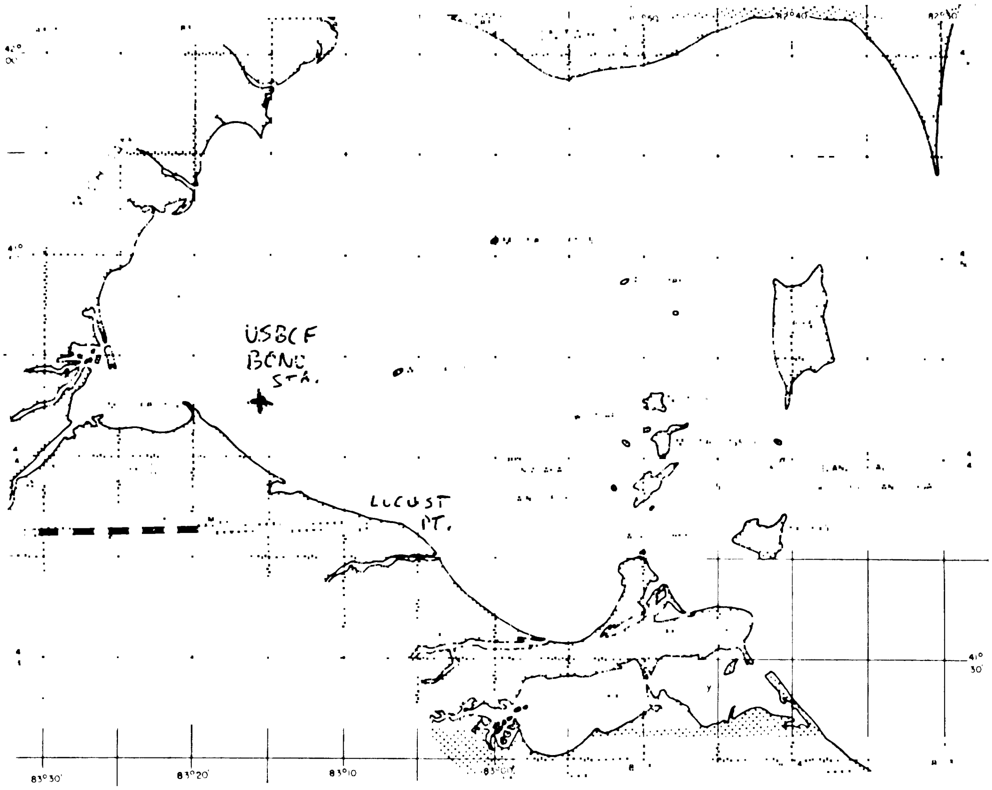


Figure 1: Western Lake Erie showing major islands and reefs plus USBCF sampling station #7 ("Bono"). Modified from Herdendorf, 1968.

fluenced by the extensive marsh habitat in the vicinity, which serves as spawning and food producing area for some species and primary habitat for others. The commercial fishery in the area consists largely of trap nets, plus a shore seine fishery for carp which operates in spring. The fisheries are somewhat restricted by test firing from Camp Perry. The chief species taken are walleye (discussed below), white bass, yellow perch, sheepshead, carp, goldfish, channel catfish, and suckers, plus a few whitefish in spring. The latter species, however, is already at or near its upper temperature limit in this area. Several forage fishes are present in abundance, partially contributing (along with the spawning reefs) to the persistence of fairly good walleye populations in the Locust Point area while those in many other areas have almost disappeared. These species include shiners, troutperch, gizzard shad, and alewife.

The Kelleys Island - Bass Island reef and the reefs off Locust Point (figure 1) are the only remaining spawning areas used by significant numbers of walleyes (Regier, et al., 1969). Walleyes tend to move counterclockwise around the basin on a yearly cycle, being concentrated near the north shore in fall and arriving on the spawning reefs during the winter. In 1968, peak spawning occurred between April 10 and 18, when water temperatures ranged from 45 to 52 degrees F. (Baker, 1969). It is generally believed that the upper limit for walleye spawning is about 55 degrees F. (W. Hartman, personal communication).

Locust Point Reef, the spawning area closest to the plant site (figure 2) showed a higher number of eggs per sample than five of the other areas in 1968, and was reported as a major spawning area for the first time (Baker, 1969). This reef is less than 3 miles offshore, while the other reefs (figure 2) range from 3 to 7 miles off. According to present best predictions if, due to unfavorable wind and current conditions, the plant discharge plume were to reach the reef area, walleye spawning would be exposed to a rise of 1 or 2 degrees. A prolonged rise might induce earlier spawning if the rise were uninterrupted, but it is more likely that the spawners would move out rather than spawn in warmer water.

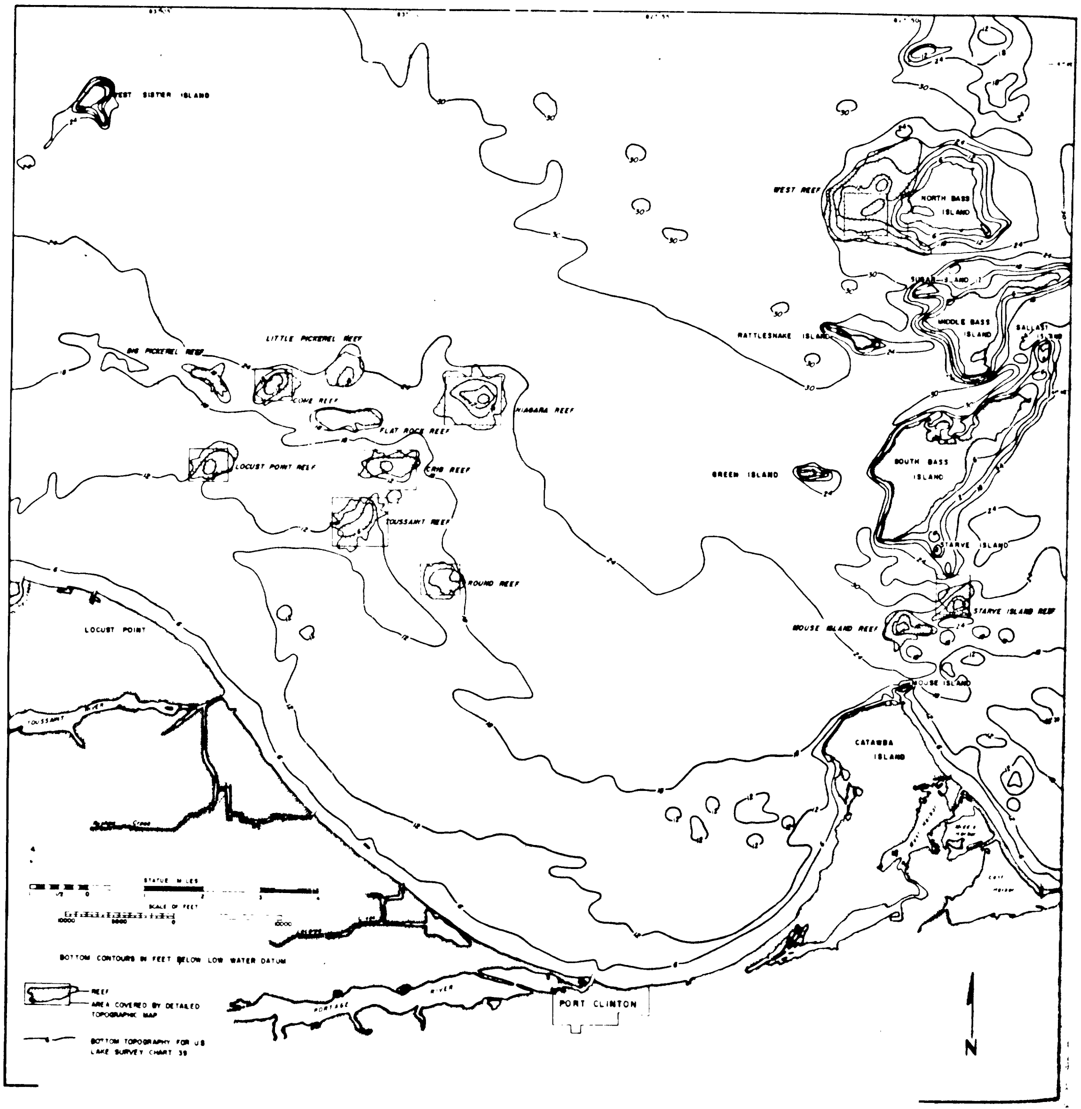


Figure 2: Major spawning reefs in western Lake Erie. From Hartley, Herdendorf, and Keller, 1966.

Another concern relates to blooms of blue-green algae, which are becoming common in western Lake Erie (Casper, 1965), and were particularly bad in 1969 (W. L. Hartman, personal communication). These algae are favored by warm temperatures and are unfavorable to forage fish and invertebrate fish food organisms (Gorham, 1965; Arnold, 1969b).

ZOOPLANKTON IN THE LOCUST POINT AREA

Zooplankton samples showed considerable differences between spring and fall, and within each season were quite consistent throughout the sampling area. May samples were dominated by cyclopoid copepods (mostly *Cyclops bicuspidatus*) and the cladoceran *Daphnia retrocurva*. In the October samples, these groups were relatively low in abundance, and the cladoceran *Bosmina* became highly dominant (see attached tables). These conditions were not unexpected on the basis of previous studies, but a large part of the *Bosmina* appeared to be of a new species or subspecies. This possibility is now being studied.

D. E. Arnold - 1/8/70

TABLE 2 COMPARISON OF WALLEYE EGG SAMPLING DATA BY INDEX STATIONS 1960 THROUGH 1968 (From Baker, 1969)

YEAR	STATION OR REEF AREA	#8 NIAGARA	#9 CRIB	#23A STARVE	#25 KELLEYS	#26 GULL	#31 TOUSSAINT	#33 WEST	TOTALS
1960	No. of Samples	8	5	---	6	5	2	1	27
	No. Eggs per Sample	202	178	---	973	189	190	60	363
	% Viable	37.5	62.2	---	49.5	44.2	46.5	66.9	49.5
1961	No. of Samples	16	22	---	15	13	---	13	79
	No. Eggs PerSample	198	609	---	910	106	---	34	406
	% Viable	23.3	18.1	---	29.0	9.7	---	11.1	21.6
1962	No. of Samples	4	4	---	5	5	4	6	28
	No. Eggs PerSample	408	256	---	146	38	316	35	180
	% Viable	44.9	35.4	---	33.4	35.2	38.6	15.7	37.4
1963	No. of Samples	12	13	9	13	13	12	11	83
	No. Eggs PerSample	131	143	189	217	112	194	1.3	142
	% Viable	30.0	27.0	46.0	30.0	21.0	33.0	7.0	31.8
1964	No. of Samples	11	8	9	10	9	8	7	62
	No. Eggs PerSample	682	301	157	1,072	58	699	4.1	455
	% Viable	38.4	50.9	62.9	11.4	12.8	32.2	55.1	35.3
1965	No. of Samples	12	10	13	11	9	11	13	79
	No. Eggs PerSample	46	91	266	3,325	155	177	11	569
	% Viable	48.7	45.3	45.7	28.8	14.8	44.6	41.1	35.4
1966	No. of Samples	18	21	23	23	15	25	16	141
	No. Eggs PerSample	119	111	262	380	14	177	43	174
	% Viable	25.4	31.9	15.9	11.5	39.7	25.9	19.2	19.4
1967	No. of Samples	23	24	21	19	1	25	10	123
	No. Eggs PerSample	121	139	279	119	3	238	2	164
	% Viable	38.3	33.5	34.9	25.2	33.3	40.6	0.0	35.3
1968	No. of Samples	26	26	20	17	---	25	13	127
	No. Eggs PerSample	45	78	63	376	---	124	6	110
	% Viable	26.1	24.8	17.8	17.1	---	26.1	34.1	21.9

REFERENCES

Arnold, D. E. 1969a. The ecological decline of Lake Erie. New York Fish Game J. 16(1):27-45.

Arnold, D. E. 1969b. Feeding studies on Daphnia pulex using seven blue-green algae. Ph. D. thesis, Cornell Univ. 89 p.

Ayers, J. C., and R. F. Anderson. 1969. Hydrological surveys for the Locust Point power plant. Spec. Rep. 45, Great Lakes Res. Div., Univ. Mich. 75 p. + app.

Baker, C. T. 1969. Walleye spawning area study in western Lake Erie. Job Completion Report F-35-R-7, Dingell-Johnson Program, Ohio Dept. Nat. Res. Mimeo. 27 p.

Casper, V. L. 1965. A phytoplankton bloom in western Lake Erie. Great Lakes Res. Div. Univ. Mich. Pub. 13:29-35.

Gorham, P. R. 1965. Toxic waterblooms of blue-green algae. P. 37-43 in C. M. Tarzwell (ed.), Biological problems in water pollution (3rd seminar). U. S. Public Health Service Pub. 999-WP-25.

Hartley, R. P., C. E. Herdendorf, and M. Keller. 1966. Synoptic water sampling survey in the western basin of Lake Erie. Great Lakes Res. Div. Univ. Mich. Pub. 15: 301-322.

Herdendorf, C. E. 1968. Sedimentation studies in the south shore reef area of western Lake Erie. Proc. 11th Conf. Great Lakes Res. 188-205.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Tech. Rep. 15, Great Lakes Fish. Comm. 101 p.

12/5/69

CURRICULUM VITAE

Dean Edward Arnold

B. Elmira, N. Y. 4/8/39, M. 1964, 1 child. S.S.# 080-30-8061

A. B. University of Rochester, 1961. General science, biology
M. S. Cornell University, 1965. Fishery biology, limnology
Ph.D. Cornell University, 1969. Aquatic ecology, fishery science, phycology.

U. S. Navy, 1961-1963 (lieutenant j.g., engineering officer of oceanographic survey ship)

Research Assistant, Cornell University, 1963-1965 (fisheries)
Research Associate, Assistant Project Leader, Warmwater Fisheries Investigations, Cornell University, 1965-1966
Teaching Assistant, Cornell University, 1966-1968 (limnology)
N. I. H. Predoctoral Fellow, Cornell University, 1967-1968 (aquatic ecology)
Assistant Research Limnologist, University of Michigan, 1969-

Professional Societies:

- American Society of Limnology and Oceanography
- International Association for Theoretical and Applied Limnology
- American Fisheries Society (Certified Fishery Scientist)
- Ecological Society of America
- International Association for Great Lakes Research

Publications and theses:

- 1966. Marking fish with dyes and other chemicals. M. S. Thesis, Cornell University.
- 1966. Marking fish with dyes and other chemicals. Tech. Paper 10, U. S. Bureau Sport Fish. Wildl. 44 p.
- 1966. Use of the jaw-injection technique for marking warm water fish. Trans. Am. Fish. Soc. 95(4): 432-433.
- 1967. An unusually dense population of the creek chub-sucker. N. Y. Fish Game J. 14(1):79-81.
- 1968. (with A. W. Eipper, et al.) Thermal pollution of Cayuga Lake by a proposed power plant. Ithaca, N. Y. 11 p.
- 1968. (with C. A. Carlson, Jr., et al.) Radioactivity and a proposed power plant on Cayuga Lake. Ithaca, N.Y. 12 p.
- 1969. The ecological decline of Lake Erie. N. Y. Fish Game J. 16(1):27-45.
- 1969. Feeding studies on Daphnia pulex using seven blue-green algae. Ph.D. thesis, Cornell University.

Radiological Analyses

The following reports by Charles C. Kidd present a part of the studies of accumulation of radionuclides in the food chain, which have been carried on with funds from Indiana and Michigan Electric Company and from Toledo Edison.

Other studies, similarly supported are incorporated in a PhD thesis by Kidd which should be completed in the near future.

These reports by Kidd have just recently been received.

J. C. Ayers

RADIOLOGICAL HEALTH RESEARCH

PROGRESS REPORT

"THE ACCUMULATION OF RADIONUCLIDES BY PONTOPOREIA AFFINIS"

Submitted by, CHARLES C. KIDD

INTRODUCTION:

Earlier experiments conducted by the writer during the period 1 Aug. 1968 thru 31 Oct. 1968 were designed to reveal the ability of the amphipod, Pontoporeia affinis, to accumulate radioactive elements in solution. In these experiments the amphipods were exposed to waste waters from a nuclear fuel reprocessing plant and a nuclear power reactor. These wastes contained significant quantities of radioactive zinc, zirconium, ruthenium, barium and cesium. Results of these experiments indicated that the organism only demonstrated an affinity for zinc as indicated by the accumulation of zinc-65. The concentration of radioactive zinc in the amphipods was approximately 250 times greater than the concentration of the isotope in solution after a 3-day exposure period. In order to confirm this observation, and to measure the ability of Pontoporeia to accumulate other radioactive elements the experiments described in this report were conducted. Some of the radioactive elements used in these experiments are peculiar to waste from nuclear facilities (activation products) and some may be present in the environment as a result of nuclear facilities operations or testing of nuclear devices (fission products). In some of the experiments the amphipods were exposed to radioactive elements in the absence of sediment from which they are known to obtain most of their food. By comparing experimental results of

tests "with" and "without" sediment those accumulated isotopes involved in metabolic processes will be identified.

METHODS AND MATERIALS:

The seven radioactive elements used in these experiments were cerium-144, manganese-54, zinc-65, cesium-137, zirconium-95, ruthenium-106 and strontium-90. A total of 14 plastic aquaria were used each containing 250 ml. of lake water. Thirty grams of sediment was added to 7 of the aquaria. Equal volumes of each solution containing a radioactive element were added to an aquarium without sediment and to one with sediment. Twelve amphipods were placed in each aquarium and all test animals were maintained at 10°C for 72 hours. At the end of this time all the water in the aquaria with sediment was slowly siphoned off into plastic cups. The amphipods were removed by flushing the sediment through a screen which retained them. Amphipods were removed from the aquaria without sediment with a small tea strainer. The 12 amphipods from each aquarium were divided into 3 groups of 4 animals each. The wet weight of each group of amphipods was determined immediately. All amphipods and water from tests involving gamma emitters with and without sediment were analysed for 200 minutes by a gamma spectrometer. Pontoporeia which had not been exposed to radioactive isotopes in the laboratory and were from the same area of Lake Michigan were also weighed and radioassayed. After adjusting each spectrum of gamma radioactivity obtained from analysis of the amphipods for the contribution of

activity from unirradiated amphipods the specific activity, picocuries (pCi) per gram, was calculated for each isotope under both sets of test conditions. The residual activity per ml. in all tests waters was also calculated. Amphipods exposed to strontium-90 were wet-digested with nitric acid and the neutralized dry residue counted for 50 minutes in a Beckman Low Background Beta Counter. A sample of unirradiated amphipods was also analysed in this manner. Waters from the strontium tests were evaporated to dryness and analysed in the low background beta counter.

RESULTS:

Tables #1 and #2 are "budgets" which reveal the fate of radionuclides used in each experiment. Significant percentages of all radioisotopes with the exception of ruthenium were removed by the amphipods in the tests without sediment. The largest accumulation multiple, (pCi per gram/pCi per ml.) resulting from this experiment was 29 as observed for manganese and zinc. (see table #3). Results of the experiment with sediment revealed that significant percentages of manganese-54, zinc-65, strontium-90 were removed by the amphipods. Accumulation multiples for these isotopes were 29, 273 and 70, respectively. It was observed also that a large percent of each isotope added became associated with the sediment and thereby available to the amphipods.

CONCLUSIONS:

The results of the experiments described above indicate that *Pontoporeia affinis* has a greater affinity for zinc than any other isotope tested. It is also concluded the accumulation of strontium and zinc are enhanced by their availability in the sediment and that their accumulation involves metabolic processes.

Experiments will be initiated shortly to determine maximum accumulation multiples for radioactive strontium, zinc and manganese. Strontium-85, a gamma emitter, will be used in these experiments to permit the simultaneous measurement of radioactivity due to all three isotopes by gamma spectrometry. Having reached a maximum specific activity test organisms will be placed in aquaria containing no added radionuclides. The loss of activity in time will permit the calculation of the effective and biological half-lives of each radioisotope in the amphipod.

TABLE #1

BUDGET OF RADIONUCLIDES FOR 72 HOURS LABORATORY UPTAKE EXPERIMENT WITHOUT SEDIMENT:

IONUCLIDE	TOTAL ACTIVITY ADDED (pCi)	ACTIVITY REMAINING IN SOLUTION (pCi)	ACTIVITY REMOVED BY AMPHIPODS (pCi)	PERCENT REMOVAL
e^{144}-Pr^{144}	820	818	2	0.24%
n^{54}	214,000	212,843	1,157	0.54%
n^{65}	32,300	32,132	168	0.52%
s^{137}	1,745	1,736	9	0.52%
r^{95}-Nb^{95}	2,950	2,948	2	0.06%
u^{106}-Rh^{106}	30,600	>30,599	<1	<0.003%
r^{90}-Y^{90}	1,825	1,819	6	0.33%

TABLE #2

BUDGET OF RADIONUCLIDES FOR 72 HOUR LABORATORY UPTAKE-EXPERIMENT WITH SEDIMENT:

ADIONUCLIDE	TOT. ACTIVITY ADDED (pCi)	ACTIVITY REMAINING IN SOL. (pCi)	ACTIVITY REMOVED BY SED. (pCi)	% RE-MOVAL	ACTIVITY REMOVED BY AMPHIPODS (pCi)	% REMOVAL
e^{144}-Pr^{144}	820	338	482	58.80%	0	0
n^{54}	214,000	30,942	182,937	85.44%	121	0.06%
n^{65}	32,300	1,696	30,541	94.50%	63	0.20%
s^{137}	1,745	280	1,465	84.00%	0	0
r^{95}-Nb^{95}	2,950	374	2,576	87.30%	0	0
u^{106}-Rh^{106}	30,600	6,833	23,764	77.61%	3	0.01%
r^{90}-Y^{90}	1,825	765	1,052	57.60%	8	0.50%

TABLE #3:

SPECIFIC ACTIVITIES AND ACCUMULATION MULTIPLES IN PONTOPOREIA AFFINIS RESULTING FROM 72 HOUR LABORATORY UPTAKE EXPERIMENTS:

ADIONUCLIDE	SPECIFIC ACTIVITY (pCi/gram)		ACCUMULATION MULTIPLE (pCi/gram / pCi/ml.)	
	WITHOUT SED.	WITH SED.	WITHOUT SED.	WITH SED.
e^{144}-Pr^{144}	46	0	20	0
n^{54}	24,450	3,641	29	29
n^{65}	3,730	1,854	29	273
s^{137}	155	0	22	0
r^{95}-Nb^{95}	109	0	9	0
u^{106}-Rh^{106}	6	71	0.8	3
r^{90}-Y^{90}	122	212	17	70

ACCUMULATION OF RADIOACTIVE ISOTOPES BY

LAKE ERIE BENTHIC WORMS:

C. Kidd, 24 July '69

ISOTOPE	SAMPLE #	TYPE	WET WT.(g)	7-DAY ACTIVITY		CONCEN-TRATION FACTOR
				In water	In worms	
Mn^{54}	1	Chironominae	0.112	4.18 $\frac{cpm}{ml}$	411 $\frac{cpm}{g}$	98.3
	2	Oligochaetes	0.129		388 "	93.0
Cs^{137}	3	Chiron.	0.259	3.95 $\frac{cpm}{ml}$	467 $\frac{cpm}{g}$	118
	4	Oligo.	0.201		323 "	81.7
Zn^{65}	5	Chiron.	0.039	2.30 $\frac{cpm}{ml}$	1692 $\frac{cpm}{g}$	736
	6	Oligo	0.176		369 "	160
Sr^{85}	7	Chiron.	----	----	----	----
	8	Oligo.	0.071	30.2 $\frac{cpm}{ml}$	676 $\frac{cpm}{g}$	22.4

ACCUMULATION OF RADIOISOTOPES BY FRESHWATER CLAMS (LAKE ERIE):

C. Kidd 24, July 1969: 72 Hour Test

ISOTOPE	SAMPLE	SOFT TISSUE WET WEIGHT	TOT. ACTIVITY IN SOFT TISSUE (cpm)	(cpm/g) CONC. OF ACTIVITY IN SOFT TISSUE	(cpm/ml) ACT. CONC. IN WATER	CONC. FACTOR IN SOFT TISSUE	WEIGHT OF SHELL	TOT. ACT. IN SHELL (cpm)	CONC. OF ACTIVITY IN SHELL (cpm/g)	CONC. FACTOR IN SHELL
Sr^{85}	8	32.1	387	12.1	19.9	0.61	30.5	533	17.5	0.88
	9	28.1	309	11.0		0.55	7.20	501	69.5	3.56
	10	32.7	139	4.25		0.21	8.30	444	53.4	2.68
	13	87.9	688	7.83		0.39	61.9	878	14.2	0.71
Cs^{137}	8	32.1	536	16.7	6.90	2.42	30.5	2011	65.9	9.55
	9	28.1	1095	39.0		5.65	7.20	1774	246	35.7
	10	32.7	1675	5.18		0.75	8.30	1164	140	20.2
	13	87.9	1428	16.2		2.34	61.9	2441	39.4	5.7
Mn^{54}	8	32.1	209	6.51	3.30	1.97	30.5	304	9.96	3.02
	9	28.1	90.0	3.20		0.97	7.20	377	52.4	15.9
	10	32.7	0	0		0	8.30	420	506	153
	13	87.9	17.0	0.19		0.06	61.9	542	8.75	2.65
Zn^{65}	8	32.1	151	4.70	3.23	1.45	305	209	6.85	2.12
	9	28.1	0	0		0	7.20	322	44.7	13.8
	10	32.7	2.00	0.06		0.02	8.30	288	34.6	10.7
	13	87.9	30.0	0.34		0.11	61.9	433	6.99	2.16

RADIOLOGICAL ANALYSIS OF
SEDIMENT SAMPLES - C. Kidd
July 24, 1969

SAMPLE NO.	SAMPLE STATION	WET WEIGHT OF SOIL SAMPLE (g)	DEPTH	GROSS √ ACTIVITY		Cs^{137} ACTIVITY	
				cpm/g	pCi/g	cpm/g	pCi/g
1	LPP-15	239.3	7 m	1.68	21.2	0.33	3.25
2	FP-9	352.1		0.68	8.57	0.07	0.69
3	FP-6	316.7		0.65	8.19	0.07	0.69
4	FP-4	432.2		0.75	9.45	0.09	0.89
5	FP-10	574.4		0.62	7.31	0.09	0.89
6	FP-8	213.5		1.91	24.1	0.43	0.42
7	FP-1	229.5		1.15	14.5	0.18	1.77
8	FP-7	131.8		1.57	19.8	0.17	1.68
9	FP-12	394.8		0.97	12.2	0.18	1.77
10	FP-3	238.8		1.79	22.6	0.40	3.94
11	FP-2	209.4		1.43	18.0	0.25	2.47
12	FP-5	205.1		1.10	13.9	0.15	1.48
13	FP-11	345.8		1.26	15.9	0.29	2.86
14	LPP-13	208.0	2 m	1.09	13.7	0.19	1.87
15	LPP-10	136.5	3 m	1.75	22.0	0.30	2.96
16	LPP-1	164.9	5.5 m	1.46	18.4	0.14	1.38
17	LPP-6	222.3	1.5 m	1.11	14.0	0.09	0.89
18	LPP-4	175.8	5.5 m	1.44	18.1	0.18	1.77
19	LPP-7	142.2	5 m	0.54	6.80	0.14	1.38
20	LPP-9	139.2	1.5 m	0.83	10.5	0.15	1.48
21	LPP-2	181.5	5 m	1.55	19.5	0.19	1.87
22	LPP-3	157.5	1.5 m	1.29	16.3	0.12	1.18

REPORT OF RADIOASSAY OF FIELD SAMPLES

SUBMITTED BY, CHARLES C. KIDD

AVE. LPP - STATION: GROSS γ - ACTIVITY = 16.1 $\frac{pCi}{g}$

Cs^{137} ACTIVITY = 1.80 pCi/g

AVE. FP - STATION: GROSS γ - ACTIVITY = 14.6 pCi/g

Cs^{137} ACTIVITY = 1.96 pCi/g

INTRODUCTION:

Radioassay of macrobenthos samples collected in July, 1968 during an environmental survey of Lake Michigan in the vicinity of The Big Rock Nuclear Power Plant indicated that levels of gross beta and gamma radioactivity in *Pontoporeia affinis* might possibly reflect the influence of radionuclides released in the waste from the plant. However, the samples taken at that time did not contain many amphipods. Moreover, there were insufficient sampling locations to discern any pattern or trend in levels of radioactivity. On October 18, 1968 the writer returned to the area and working off The Great Lakes Research Division's ship "The Mysis", obtained more benthos samples from nine sampling points (see figures #1 and #2) in the vicinity of The Big Rock Nuclear Power Plant. The objective of the study described in this report is to detect any pattern in the distribution of radioactivity as results from the radioassay of the amphipods collected. The degree to which *Pontoporeia affinis* responds to the low levels of radioactivity encountered in the study area is reflective of their usefulness as biological indicators of environmental radioactivity.

METHODS AND MATERIALS:

Bottom samples were taken with a Ponar Dredge. The dredge was lowered four times at each sampling point. This represented a sampling area of approximately 0.25 square meters. Sampling depth ranged from 70 feet to 300 feet. All samples were washed free of mud and put in 1-pint Mason Jars. A small amount of Formalin was added to preserve each sample. In the laboratory the *Pontoporeia* were picked from each sample and weighed. They were then wet digested in nitric acid. The neutralized residue was dried on stainless steel planchets and analysed for 200 minutes in a gamma spectrometer. The samples were also analysed for 200 minutes in The Beckman Low-Background Beta Counter. The average gamma detection efficiency for the 5 inch NaI(Tl) crystal and multichannel analyser combination is 20% over the energy range of 0.02 to 2.0 million electron volts. This value was used to calculate the gross gamma radioactivity as indicated by the 200 minute count. The efficiency of the low-background beta counter was 42% for gross beta counting. Gross gamma and beta radioactivity was calculated and recorded as picocuries per gram (pCi/gram) of amphipod (see table #1).

RESULTS:

Gross beta radioactivity in the amphipods ranged from 0.55 to 10.93 pCi/gram. The range of gross gamma radioactivity in the amphipods was 4.07 to 40.20 pCi/gram. When gross beta and gamma activities were plotted on a scaled map of the study area the

patterns of radioactivity shown in figures #1 and #2 were drawn.

CONCLUSIONS:

The patterns of both types of radioactivity reveal the influence of the nuclear power plant on levels of environmental radioactivity. Water from an area near the discharge channel of the power plant was previously assayed and contained 54 pCi per liter, gross gamma activity. Gross gamma activity in P. affinis used in this experiment apparently exceeds the concentration in the water tested by from 76 to 745 times. More water samples from the study area are being analysed for gross radioactivity. The results of these tests will be compared with levels of radioactivity reported for the study area prior to plant operation.

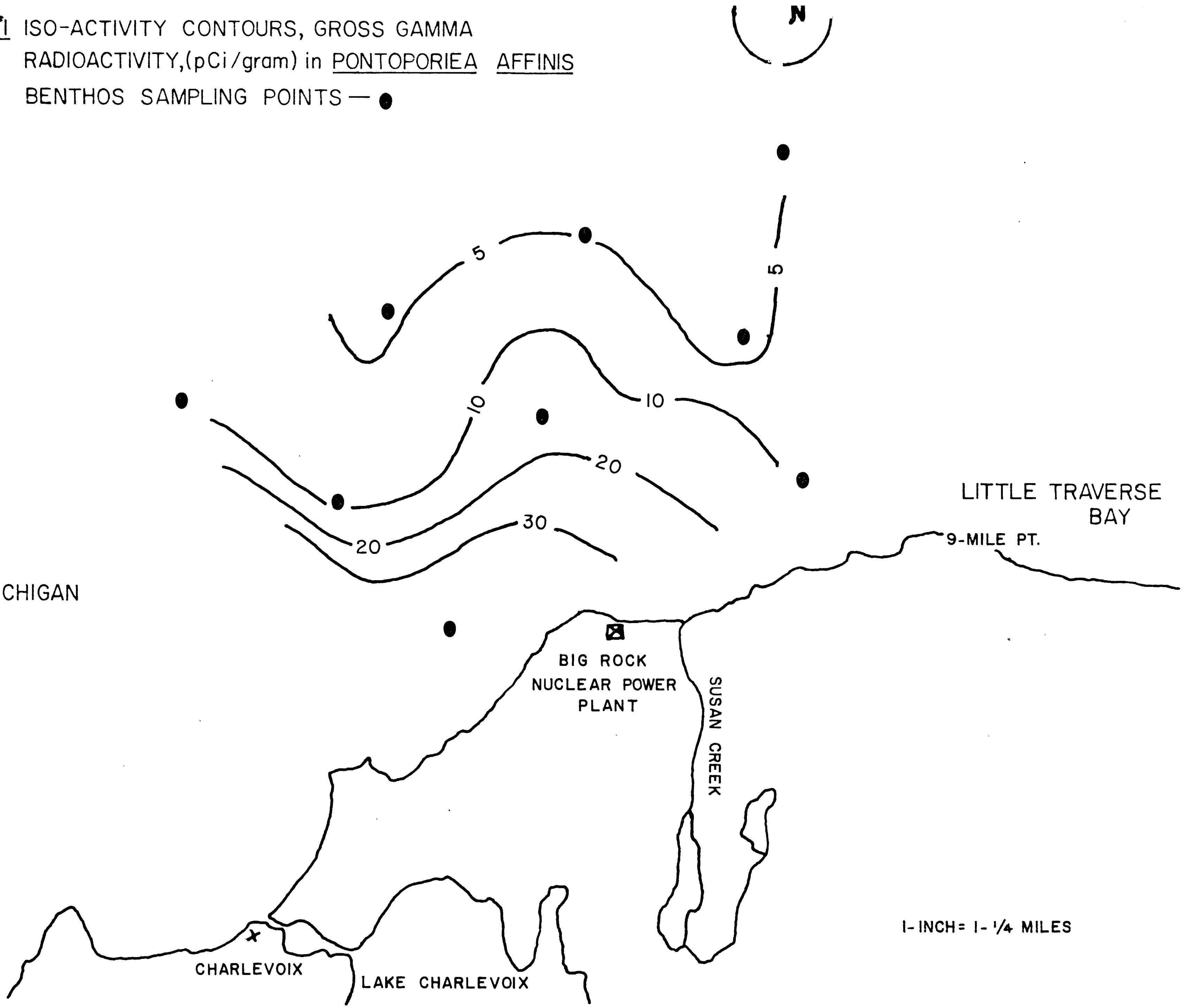
TABLE #1:

RESULTS OF RADIOASSAY OF PONTOPOREIA AFFINIS FROM BENTHOS SAMPLES TAKEN IN THE VICINITY OF THE BIG ROCK NUCLEAR POWER PLANT:

SAMPLING POINT*	WET WEIGHT OF SAMPLE (GRAMS)	RADIOACTIVITY (pCi/gram) GROSS BETA	GROSS GAMMA
1	0.89	1.66	7.83
2	1.79	1.27	4.20
3	1.22	1.44	4.91
4	1.65	1.25	4.07
5	1.32	1.69	7.05
6	0.74	1.10	14.69
7	2.32	0.55	4.86
8	0.10	3.44	40.20
9	0.79	10.93	9.86

*SEE FIGURES 1 & 2 FOR LOCATION OF SAMPLING POINTS.

FIGURE #1 ISO-ACTIVITY CONTOURS, GROSS GAMMA RADIOACTIVITY, (pCi/gram) in <u>PONTOPORIEA AFFINIS</u>
BENTHOS SAMPLING POINTS — ●



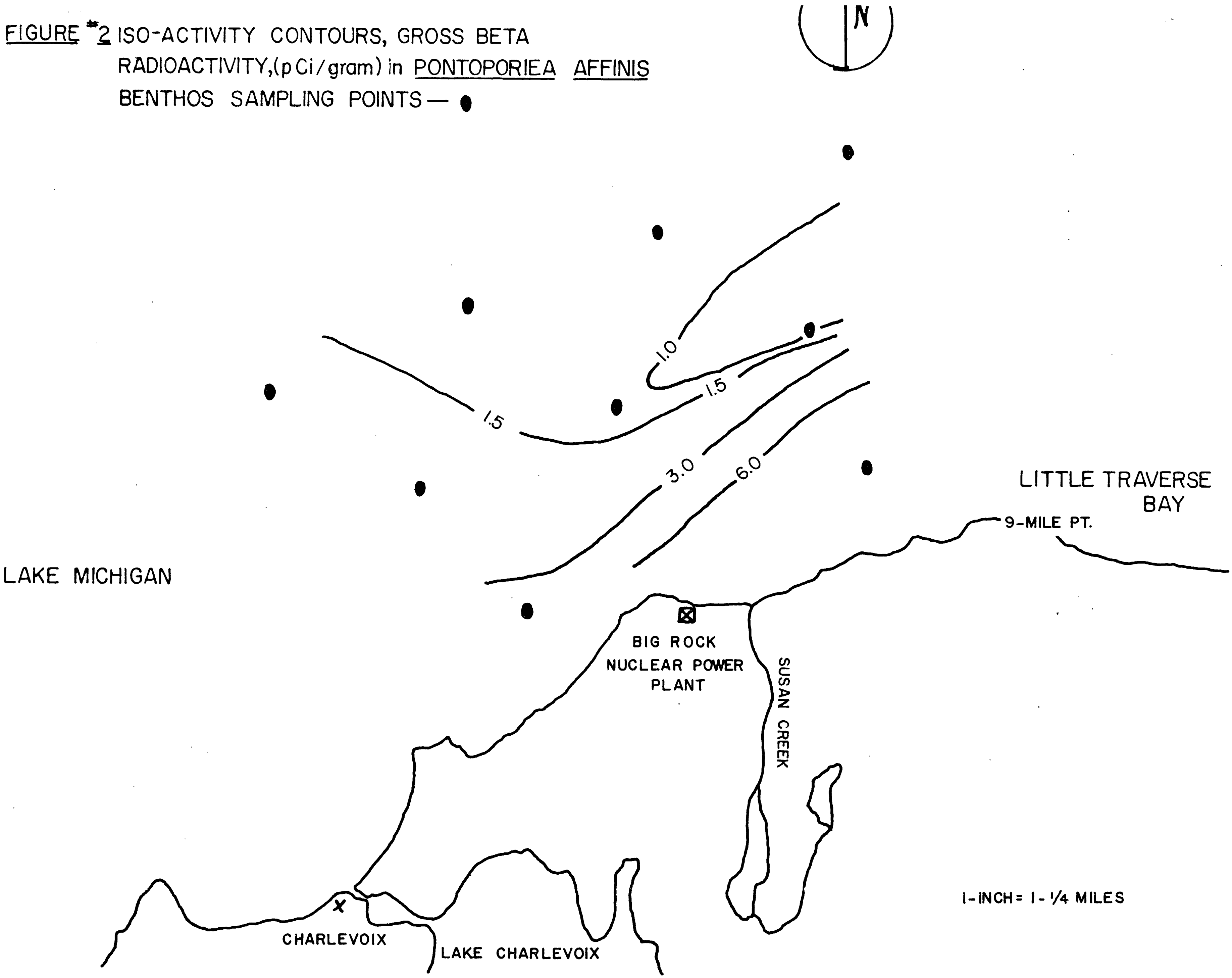


FIGURE #2 ISO-ACTIVITY CONTOURS, GROSS BETA RADIOACTIVITY, (pCi/gram) in PONTOPORIEA AFFINIS
BENTHOS SAMPLING POINTS — ●

HYDROLOGICAL SURVEYS FOR THE LOCUST POINT POWER PLANT

PART IV. The 1969 PHYTOPLANKTON COLLECTIONS IN THE LOCUST POINT REGION

John C. Ayers
Robert F. Anderson
Norbert W. O'Hara

Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

July 1970

THE 1969 PHYTOPLANKTON COLLECTIONS IN THE LOCUST POINT REGION

On May 15 and 16, 1969, phytoplankton collections were made at 11 stations in the immediate environs of Locust Point. Figure 1 presents the station positions of the May survey. Appendix Tables 1-12 inclusive give the total phytoplankton species composition and the phytoplankton species and numbers collected at each station of the May survey. Table 1 summarizes the dominant species of the May collections.

During 21-29 October 1969 phytoplankton collections were made at 20 stations in the immediate environs of Locust Point. Figure 2 shows the station positions of the October survey. The total area covered in October was not significantly different from that covered in May; the difference in number of stations collected is due to insertion of several stations at positions that were not occupied in May. Appendix Tables 13-33 give the total phytoplankton species population as well as the phytoplankton species and numbers collected at each of the Locust Point stations in October. Table 2 summarizes the dominant species of the October collections.

The Locust Point phytoplankton population in May of 1969 was composed almost entirely of diatoms, with very minor contributions by green algae and blue-green algae. In May the heavily dominant species were the diatoms *Fragilaria capucina*, *Melosira binderana* and *Melosira granulata* combined (combined because their colonies were commonly intertwined, and though cells could be seen well enough to count by focusing the microscope through, the underneath cells could not be seen well enough to identify them to species), and *Diatoma tenue v. elongatum* with the latter being consistently the third most abundant species in the station collections. One to five species of green algae were taken at each station of the May survey, a total of 14 green algae species in all being collected. At each station of the May survey representatives of the blue-green

algae, identified as Oscillatoria spp., were collected in small numbers; no examples of the troublesome species Aphanizomenon flos-aquae were taken during this survey.

The October phytoplankton collections were characterized by having a much greater variety of species present at each station than had been the case in May. They were also characterized by having lower total numbers of cells per liter and generally lower numbers of cells per species. In the October collections the diatoms remained dominant by a slight margin in numbers of cells, with green algae of 55 species in second place by numbers, and blue-green algae belonging to 16 species in third place numberswise. Blue-greens of the genus Aphanizomenon were present in all but two stations of the October survey. The relative decline in diatom dominance, and the rise of green algae and blue-greens into nearly-dominant positions between May and October can at present be taken only to possibly represent a seasonal deterioration in basic water quality which may be typical of the region, or which may be only a part of a more widespread peculiarity of 1969.

Flagellates, not found in the May collections, had become abundant by October.

As a means of showing and comparing the relative phytoplankton populations in the immediate environs of Locust Point in 1969, the following comparison table has been devised.

Judging water quality by the types of the three most dominant (numerous) plankters present (Table 2) indicates that the poorest water was found at Station PL-1 off Turtle Creek. At this station the dominant organism was the blue-green alga Oscillatoria, the second most dominant was the blue-green Aphanizomenon flos-aquae, and the diatom Cyclotella occupied third place. Another station adjudged to exhibit poor water quality was Station PL-7 where the dominant organism was the flagellate Cryptomonas with the blue-green

Comparison Table

Locust Point phytoplankton, May versus October 1969

	May			October		
	No. of species*	Mean No. of cells/liter per station	Range, Nos. cells/liter per station	No. of species*	Mean No. of cells/liter per station	Range, Nos. cells/liter per station
Diatoms	17	4,450,000	$1.9\text{-}11.9 \times 10^6$	20	1,039,000	$0.1\text{-}1.7 \times 10^6$
Green Algae	14	4,450	$1\text{-}17 \times 10^3$	55	666,000	$0.07\text{-}1.3 \times 10^6$
Flagellates	0	-----	-----	6	321,000	$85\text{-}671 \times 10^3$
Blue-Greens	1	5,000	$1\text{-}15 \times 10^3$	16	423,000	$0.07\text{-}1.4 \times 10^6$

* Identified species, unidentified single species (sp.), and unidentified plural species (spp.) combined.

Oscillatoria in second place and the diatom *Coscinodiscus rothii* third.

Continuing with these criteria, water of questionable quality (in which the second and third dominants were the blue-green *Oscillatoria* and the flagellate *Cryptomonas* respectively) was present at Stations PL-13, PL-17, PL-18, and PL-20.

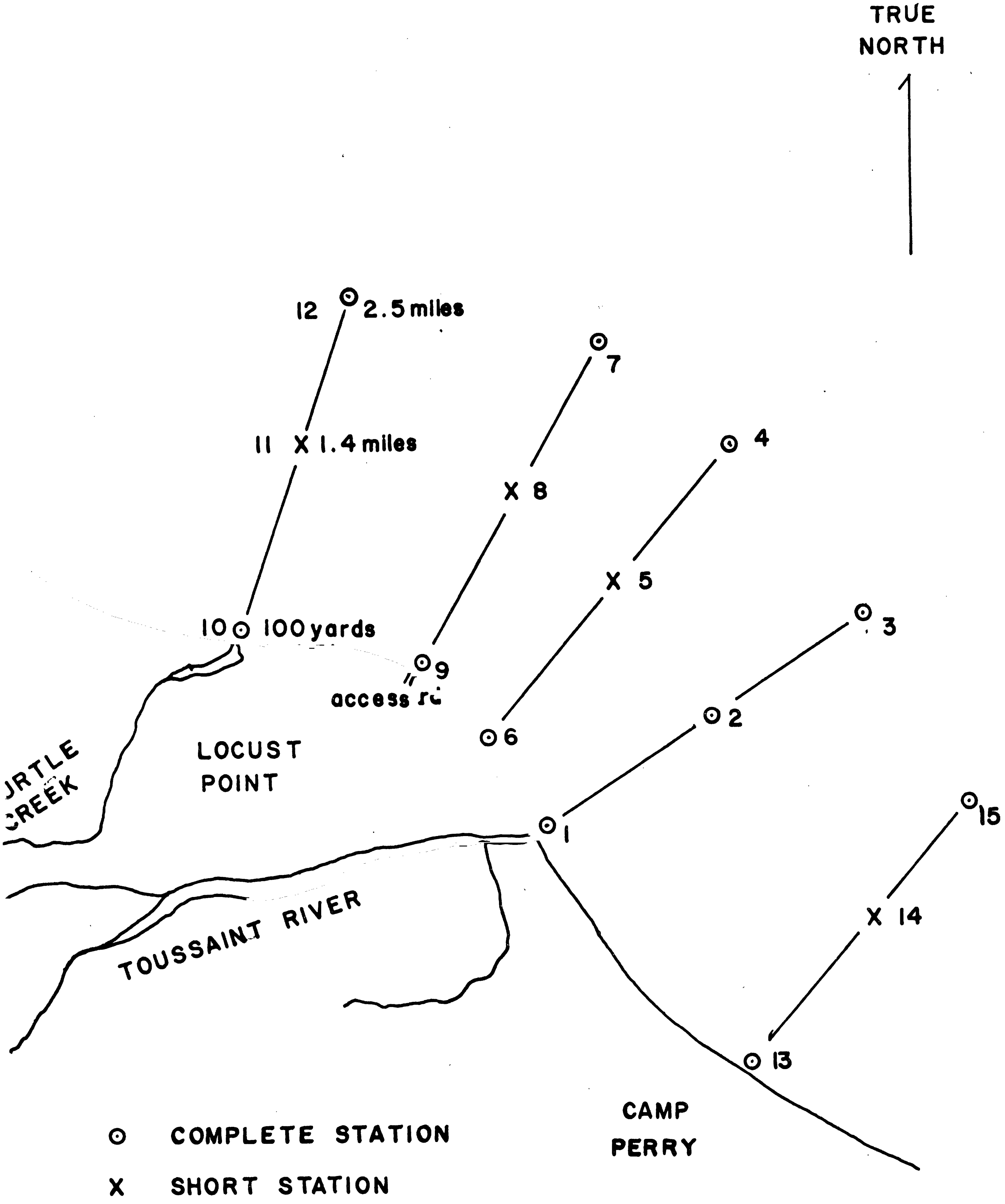
Table 2 permits other assessments of relative quality of water at the October stations. If we reason that stations with diatoms in the three most dominant positions were stations with good quality of water, we may then indicate that good quality of water was present at Stations PL-10, PL-11, and PL-12.

In a more realistic sense, however, it is not good nor meaningful practice to attribute to such indications of water quality at the various stations anything more than a certain illustrative value. In the clearer waters of eastern Lake Michigan small but discrete water masses of visible color differences can, under good observing conditions, be seen to be progressing one after the other in the alongshore current. Color indications of separate water masses could not be expected to be visible in the turbid alongshore currents of Locust Point. The

patchy distributions of poor, intermediate, and good water quality as read from the October phytoplankton dominants can, in the present state of our knowledge of the Locust Point area, be interpreted only to mean that the alongshore currents of Lake Erie are in autumn like those of Lake Michigan in that (in the relatively calm weather when small boats can work) there pass along the shore discrete water-masses of different origins with different phytoplankton contents.

Figure 1. STATION MAP OF LOCUST POINT PROJECT

MAY 1969, SAMPLING



APPENDIX

Table 1

Phytoplankton Population

Locust Point, 15-16 May 1969

Diatoms

Diatoma tenue v. elongatum
Melosira binderana
Melosira granulata
Synedra ulna
Synedra acus
Fragilaria intermedia
Fragilaria capucina
Fragilaria crotonensis
Asterionella formosa
Cyclotella spp.
Navicula spp.
Tabellaria fenestrata
Surirella spp.
Nitzschia spp.
Stephanodiscus spp.
Cymbella spp.
Gomphonema spp.

Greens

Ulothrix spp.
Pediastrum duplex
Scenedesmus abundans
Scenedesmus quadricauda
Dictyosphaerium pulchellum
Ankistrodesmus spp.
Ankistrodesmus falcatus
Scenedesmus spp.
Micractinium pusillum
Oocystis solitaria
Lagerheimia longiseta
Golenkinia radiata
Actinastrum hantzschii
Closteriopsis longissima

Blue-Greens

Oscillatoria spp.

APPENDIX

Table 2

Phytoplankton Composition

Station LPP-1, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria sp. (BG)	---	3,747
Fragilaria crotonensis (D)	1,874	51,524
Ankistrodesmus falcatus (G)	---	937
Diatoma tenue v. elongatum (D)	42,156	287,598
Melosira binderana (D)	66,513	526,482
Asterionella formosa (D)	6,558	49,651
Fragilaria capucina (D)	49,651	2,243,636
Cyclotella sp. (D)	---	7,494
Navicula sp. (D)	---	937
Oocystis solitaria (G)	---	937
Scenedesmus quadricauda (G)	---	937
Synedra ulna (D)	---	937
Tabellaria fenestrata (D)	4,684	30,914
Surirella sp. (D)	---	937
		3,206,000

APPENDIX

Table 3

Phytoplankton Composition

Station LPP-2, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna (D)	---	17,666
Synedra acus (D)	---	6,625
Tabellaria fenestrata (D)	2,208	15,458
Pediastrum duplex (G)	---	2,208
Melosira binderana & M. granulata combined (D)	516,742	4,891,385
Diatoma tenue v. elongatum (D)	99,374	1,355,896
Asterionella formosa (D)	24,291	249,538
Fragilaria crotonensis (D)	4,417	117,040
Fragilaria capucina (D)	105,998	5,284,462
Cyclotella sp. (D)	---	6,625
Scenedesmus abundans (G)	---	2,208
Oocystis solitaria (G)	---	2,208
Oscillatoria sp. (BG)	---	2,208
		11,953,000

APPENDIX

Table 4

Phytoplankton Composition

Station LPP-3, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Diatoma tenue v. elongatum (D)	47,917	242,675
Oscillatoria sp. (BG)	---	1,546
Ulothrix sp. (G)	---	1,546
Melosira binderana (D)	61,828	930,512
Synedra acus (D)	---	4,637
Synedra ulna (D)	---	6,183
Fragilaria intermedia (D)	17,003	630,646
Fragilaria capucina (D)	4,637	98,925
		1,916,000

APPENDIX

Table 5

Phytoplankton Composition

Station LPP-4, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna (D)	---	13,138
Tabellaria fenestrata (D)	10,049	57,202
Diatoma tenue v. elongatum (D)	66,478	672,510
Melosira binderana & M. granulata combined (DD)	202,526	937,649
Fragilaria crotonensis (D)	1,546	58,748
Asterionella formosa (D)	17,006	135,275
Fragilaria capucina (D)	85,030	3,237,324
Lagerheimia longiseta (G)	---	773
Golenkinia radiata (G)	---	773
Cyclotella sp. (D)	---	3,865
Oscillatoria sp. (BG)	---	2,319
Dictyosphaerium pulchellum (G)	---	1,546
Scenedesmus quadricauda (G)	---	773
Synedra acus (D)	---	2,319
		5,124,000

APPENDIX

Table 6

Phytoplankton Composition

Station LPP-6, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis (D)	2,132	14,924
Surirella sp. (D)	---	1,066
Synedra ulna (D)	---	6,396
Synedra acus (D)	---	1,066
Dictyosphaerium pulchellum (G)	---	1,066
Ankistrodesmus sp. (G)	---	1,066
Oscillatoria sp. (BG)	---	2,132
Tabellaria fenestrata (D)	7,462	33,046
Diatoma tenue v. elongatum (D)	74,620	380,562
Melosira binderana & M. granulata combined (DD)	105,534	891,176
Fragilaria capucina (D)	49,036	1,557,426
Scenedesmus abundans (G)	---	1,066
Closteriopsis longissima (G)	---	1,066
		2,892,000

APPENDIX

Table 7

Phytoplankton Composition

Station LPP-7, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna (D)	---	4,986
Surirella sp. (D)	---	997
Oocystis solitaria (G)	---	997
Melosira binderana & M. granulata combined (DD)	101,714	622,253
Diatoma tenue v. elongatum (D)	50,857	283,205
Asterionella formosa (D)	9,972	81,770
Tabellaria fenestrata (D)	3,989	12,964
Fragilaria capucina (D)	49,860	1,471,867
Micractinium pusillum (G)	---	1,994
Oscillatoria sp. (BG)	---	1,994
		2,483,000

APPENDIX

Table 8

Phytoplankton Composition

Station LPP-9, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp. (BG)	---	5,888
Micractinium pusillum (G)	---	1,472
Scenedesmus quadricauda (G)	---	1,472
Synedra ulna (D)	---	8,832
Cyclotella spp. (D)	---	10,304
Gomphonema sp. (D)	---	1,472
Stephanodiscus sp. (D)	---	2,944
Synedra acus (D)	---	7,360
Melosira binderana & M. granulata combined (DD)	113,344	1,149,632
Asterionella formosa (D)	5,888	27,968
Tabellaria fenestrata (D)	1,472	8,832
Diatoma tenue v. elongatum (D)	75,072	450,432
Fragilaria crotonensis (D)	2,944	79,488
Fragilaria capucina (D)	41,216	585,856
		2,341,000

APPENDIX

Table 9

Phytoplankton Composition

Station LPP-10, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis (D)	6,183	74,191
Synedra acus (D)	---	15,457
Synedra ulna (D)	---	6,183
Oscillatoria spp. (BG)	---	15,457
Melosira binderana & M. granulata combined (DD)	420,417	3,159,309
Fragilaria capucina (D)	108,196	2,550,323
Scenedesmus sp. (G)	---	3,091
Cyclotella sp. (D)	---	9,274
Ankistrodesmus falcatus (G)	---	3,091
Nitzschia sp. (D)	---	9,274
Diatoma tenue v. elongatum (D)	272,034	1,415,815
Asterionella formosa (D)	12,365	83,465
Tabellaria fenestrata (D)	6,183	27,823
		7,372,000

APPENDIX

Table 10

Phytoplankton Composition

Station LPP-12, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna (D)	---	4,314
Oscillatoria sp. (BG)	---	6,470
Actinastrum hantzschii (G)	---	2,157
Diatoma tenue v. elongatum (D)	42,058	208,131
Melosira binderana & M. granulata combined (DD)	73,331	815,270
Asterionella formosa (D)	4,314	38,822
Tabellaria fenestrata (D)	5,392	20,490
Fragilaria capucina (D)	21,570	628,707
Scenedesmus abundans (G)	---	1,078
Cyclotella sp. (D)	---	3,235
		1,728,000

APPENDIX

Table 11

Phytoplankton Composition

Station LPP-13, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Scenedesmus quadricauda (G)	---	1,546
Oscillatoria spp. (BG)	---	12,368
Stephanodiscus sp. (D)	---	9,276
Synedra acus (D)	---	10,822
Dictyosphaerium pulchellum (G)	---	6,184
Ankistrodesmus sp. (G)	---	3,092
Actinastrum hantzschii (G)	---	3,092
Cyclotella spp. (D)	---	9,276
Micractinium pusillum (G)	---	3,092
Synedra ulna (D)	---	6,184
Tabellaria fenestrata (D)	6,184	30,920
Diatoma tenue v. elongatum (D)	123,680	1,004,900
Melosira binderana & M. granulata combined (DD)	536,462	5,468,202
Fragilaria capucina (D)	40,196	1,456,332
Cymbella sp. (D)	---	1,546
Asterionella formosa (D)	4,638	30,920
		8,057,000

APPENDIX

Table 12

Phytoplankton Composition

Station LPP-15, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp. (BG)	---	6,624
Ankistrodesmus sp. (G)	---	2,208
Navicula sp. (D)	---	1,104
Synedra acus (D)	---	4,416
Fragilaria crotonensis (D)	1,104	37,536
Melosira binderana & M. granulata combined (DD)	59,616	623,760
Diatoma tenue v. elongatum (D)	44,160	195,408
Tabellaria fenestrata (D)	9,936	40,848
Asterionella formosa (D)	1,104	11,040
Fragilaria capucina (D)	28,704	1,065,360
Synedra ulna (D)	---	2,208
Cyclotella sp. (D)	---	6,624
Closteriopsis longissima (G)	---	1,104
		1,998,000

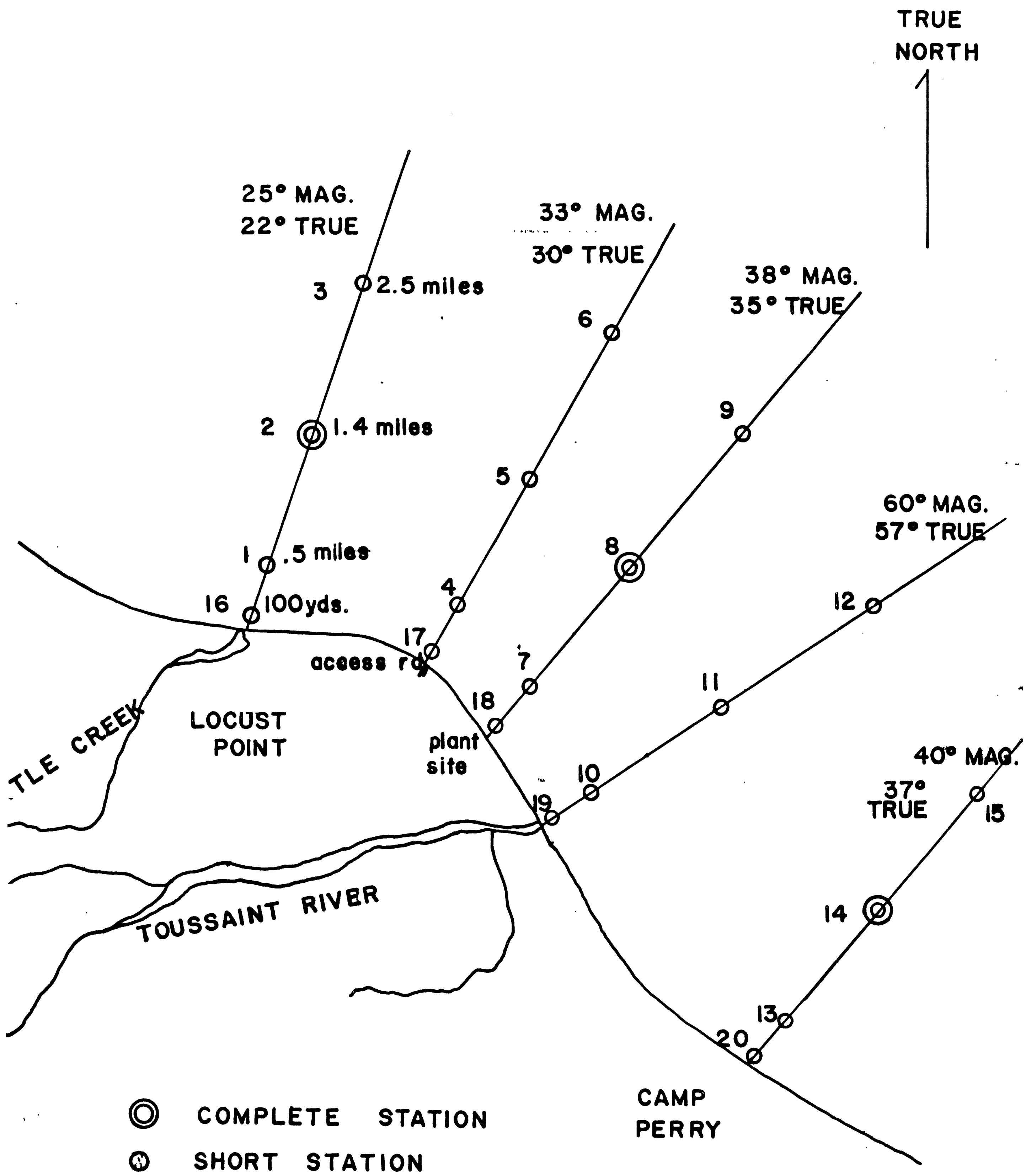
Table 1

Summary of May phytoplankton dominants

Station	Most Dominant	Second Dominant	Third Dominant
LPP-1	Fragilaria capucina (D)	Melosira binderana (D)	Diatoma tenue v. elongatum (D)
LPP-2	Fragilaria capucina (D)	Melosira binderana & M. granulata combined (DD)	Diatoma tenue v. elongatum (D)
LPP-3	Melosira binderana (D)	Fragilaria intermedia (D)	Diatoma tenue v. elongatum (D)
LPP-4	Fragilaria capucina (D)	M. binderana & granulata combined (DD)	Diatoma tenue v. elongatum (D)
LPP-6	Fragilaria capucina (D)	M. binderana & granulata combined (DD)	Diatoma tenue v. elongatum (D)
LPP-7	Fragilaria capucina (D)	M. binderana & granulata combined (DD)	Diatoma tenue v. elongatum (D)
LPP-9	M. binderana & granulata combined (DD)	Fragilaria capucina (D)	Diatoma tenue v. elongatum (D)
LPP-10	M. binderana & granulata combined (DD)	Fragilaria capucina (D)	Diatoma tenue v. elongatum (D)
LPP-12	M. binderana & granulata combined (DD)	Fragilaria capucina (D)	Diatoma tenue v. elongatum (D)
LPP-13	M. binderana & granulata combined (DD)	Fragilaria capucina (D)	Diatoma tenue v. elongatum (D)
LPP-15	Fragilaria capucina (D)	M. binderana & granulata combined (DD)	Diatoma tenue v. elongatum (D)

Figure 2. STATION MAP OF LOCUST POINT

OCTOBER 1969, SAMPLING



APPENDIX

Table 13

Phytoplankton Population

Locust Point Samples
October 1969

Diatoms

Coscinodiscus spp.
Coscinodiscus rothii var. subsalsa
Cyclotella spp.
Melosira granulata
Melosira binderana
Melosira sp.
Stephanodiscus niagarae
Stephanodiscus sp.
Fragilaria intermedia
Fragilaria crotonensis
Fragilaria construens
Fragilaria capucina
Fragilaria pinnata
Synedra sp.
Nitzschia spp.
Surirella sp.
Navicula sp.
Amphora ovalis
Diatoma vulgare
Meridion circulare

Greens

Coelastrum sphaericum
Coelastrum microporum
Coelastrum reticulatum
Coelastrum sp.
Pediastrum duplex
Pediastrum simplex
Pediastrum spp.
Dictyosphaerium pulchellum
Dictyosphaerium ehrenbergianum
Ankistrodesmus falcatus
Ankistrodesmus spp.
Scenedesmus abundans
Scenedesmus sp.
Scenedesmus acuminatus
Scenedesmus bijuga
Scenedesmus dimorphus
Scenedesmus incrassatulus
Scenedesmus quadricauda
Scenedesmus armatus
Scenedesmus arcuatus
Scenedesmus acutiformis
Staurastrum sp. (desmid)

Greens (Cont.)

Ulothrix spp.
Oocystis spp.
Oocystis borgei
Oocystis solitaria
Schroederia sp.
Schroederia judayi
Schroederia setigera
Actinastrum hantzschii
Closterium sp. (desmid)
Closteriopsis longissima
Tribonema spp.
Cosmarium sp. (desmid)
Nephrocytium sp.
Lagerheimia longiseta
Gloeocystis spp.
Gloeocystis major
Tetraëdron sp.
Tetraëdron caudatum
Tetraëdron lunula
Tetraëdron minimum
Tetraëdron trigonum
Selenastrum bibraianum
Selenastrum sp.
Dimorphococcus sp.
Dimorphococcus lunatus
Kirchneriella sp.
Kirchneriella lunaris
Kirchneriella elongata
Crucigenia quadrata
Crucigenia spp.
Quadrigula lacustris
Golenkinia radiata
Tetrastrum spp.
Sorastrum spinulosum
Treubaria setigerum
Sorastrum sp.

Blue-Greens

Oscillatoria spp.
Anabaena spp.
Anabaena circinalis
Aphanizomenon flos-aquae
Aphanizomenon sp.
Gomphosphaeria spp.

Table 13 (Cont.)

Blue-Greens (Cont.)

Gomphosphaeria lacustris
Chroococcus sp.
Aphanocapsa sp.
Microcystis aeruginosa
Merismopedia sp.
Chroococcus limneticus
Chroococcus dispersus
Dactylococcopsis smithii
Coelosphaerium sp.
Coelosphaerium naegelianum

Flagellates

Peridinium spp.
Cryptomonas spp.
Chlamydomonas spp.
Mallomonas spp.
Euglena sp.
Cystodinium sp.

APPENDIX

Table 14

Phytoplankton Composition

Station PL-1, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Nephrocytium sp. (G)		14,840
Tetraëdron minimum (G)		3,710
Chroococcus limneticus (BG)		7,420
Tetraëdron caudatum (G)		3,710
Coscinodiscus rothii (D)		18,550
Microcystis aeruginosa (BG)		7,420
Cystodinium sp. (F)		18,550
Crucigenia sp. (G)		11,130
Pediastrum spp. (G)		25,970
Gomphosphaeria spp. (BG)		25,970
Schroederia judayi (G)		3,710
Anabaena sp. (BG)		14,840
Tetraëdron lunula (G)		85,330
Ankistrodesmus falcatus (G)		22,260
Gloeocystis spp. (G)		40,810
Dictyosphaerium pulchellum (G)		66,780
Gloeocystis major (G)		33,390
Oscillatoria spp. (BG)		359,870
Oocystis spp. (G)		81,620
Coelastrum sphaericum (G)		59,360
Ulothrix spp. (G)		51,940
Cyclotella spp. (D)		92,750
Aphanizomenon flos-aquae (BG)		159,530
Cryptomonas spp. (F)		29,680
Scenedesmus bijuga (G)		63,070
Scenedesmus abundans (G)		22,260
Scenedesmus quadricauda (G)		40,810
Scenedesmus dimorphus (G)		14,840
Closterium sp. (G)		3,710
Nitzschia sp. (D)		3,710
Tribonema sp. (G)		7,420
Sorastrum spinulosa (G)		3,710
Chlamydomonas spp. (F)		37,100
Oocystis solitaria (G)		25,970
		1,461,000

APPENDIX

Table 15

Phytoplankton Composition

Station PL-2, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Chroococcus limneticus (BG)		3,710
Pediastrum spp. (G)		29,680
Coelastrum sphaericum (G)		63,070
Gloeocystis sp. (G)		11,130
Dictyosphaerium pulchellum (G)		29,680
Gomphosphaeria lacustris (BG)		25,970
Oocystis borgei (G)		25,970
Oocystis solitaria (G)		33,390
Cyclotella spp. (D)		215,180
Coscinodiscus rothii (D)		89,040
Cryptomonas spp. (F)		115,010
Chlamydomonas spp. (F)		107,590
Ankistrodesmus falcatus (G)		59,360
Mallomonas sp. (F)		11,130
Scenedesmus abundans (G)		107,590
Scenedesmus quadricauda (G)		44,520
Scenedesmus incrassatulus (G)		22,260
Scenedesmus bijuga (G)		33,390
Scenedesmus armatus (G)		37,100
Cosmarium sp. (G)		3,710
Closterium sp. (G)		7,420
Scenedesmus acuminatus (G)		11,130
Nephrocytium sp. (G)		14,840
Tetraëdron sp. (G)		14,840
Actinastrum hantzschii (G)		11,130
Crucigenia quadrata (G)		33,390
Aphanizomenon flos-aquae (BG)		48,230
Oscillatoria spp. (BG)		196,630
Ulothrix spp. (G)		63,070
Anabaena sp. (BG)		11,130
Nitzschia spp. (D)		51,940
Melosira granulata (D)	215,180	916,370
Kirchneriella sp. (G)		3,710
Golenkina radiata (G)		3,710
Merismopedia sp. (BG)		3,710
Stephanodiscus niagarae (D)		3,710
Schroederia judayi (G)		14,840
Peridinium sp. (F)		11,130
		2,489,000

APPENDIX

Table 16

Phytoplankton Composition

Station PL-3, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Staurastrum sp. (G) (desmid)		14,840
Crucigenia spp. (G)	11,130	40,810
Tetraëdron lunula (G)		18,550
Tetrastrum sp. (G)		3,710
Ankistrodesmus falcatus (G)		18,550
Cystodinium sp. (F)		7,420
Merismopedia sp. (BG)		3,710
Anabaena sp. (BG)		3,710
Kirchneriella elongata (G)		3,710
Gloeocystis sp. (G)		7,420
Oscillatoria spp. (BG)		178,080
Oocystis sp. (G)		18,550
Cryptomonas spp. (F)		63,070
Chlamydomonas spp. (F)		63,070
Cyclotella spp. (D)		51,940
Coscinodiscus sp. (D)		63,070
Peridinium spp. (F)		3,710
Pediastrum spp. (G)		37,100
Ulothrix sp. (G)		11,130
Dictyosphaerium pulchellum (G)		7,420
Coelastrum sphaericum (G)		44,520
Scenedesmus quadricauda (G)		40,810
Scenedesmus abundans (G)		85,330
Scenedesmus bijuga (G)		14,840
Scenedesmus incrassatula (G)		7,420
Melosira granulata (D)	185,500	712,320
Actinastrum hantzschii (G)		3,710
Tetraëdron trigonum (G)		3,710
Gomphosphaeria sp. (BG)		7,420
Gloeocystis major (G)		7,420
Chroococcus dispersus (BG)		3,710
Schroederia judayi (G)		3,710
		1,554,000

APPENDIX

Table 17

Phytoplankton Composition

Station PL-4, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Dactylococcopsis smithii (BG)		11,130
Kirchneriella sp. (G)		7,420
Stephanodiscus sp. (D)		18,550
Tetrastrum sp. (G)		11,130
Nephrocytium sp. (G)		18,550
Golenkinia radiata (G)		11,130
Cystodinium sp. (F)		14,840
Staurastrum sp. (G) (desmid)		14,840
Coscinodiscus spp. (D)		200,340
Cyclotella spp. (D)		753,130
Coelastrum sphaericum (G)		96,460
Euglena sp. (F)		18,550
Oocystis solitaria (G)		29,680
Oocystis spp. (mostly borgei) (G)		92,750
Dictyosphaerium pulchellum (G)		51,940
Gomphosphaeria spp. (lacustris, aponina) (BG)		66,780
Crucigenia spp. (G)		33,390
Pediastrum spp. (G)		37,100
Tetraëdron caudatum (G)		14,840
Tetraëdron lunula (G)		44,520
Gloeocystis sp. (G)		18,550
Merismopedia sp. (BG)		3,710
Actinastrum hantzschii (G)		29,680
Cryptomonas spp. (F)		352,450
Chlamydomonas spp. (F)		155,820
Ankistrodesmus falcatus (G)		81,620
Peridinium spp. (F)		70,490
Mallomonas spp. (F)		59,360
Scenedesmus abundans (G)		233,730
Scenedesmus incrassatulus (G)		44,520
Scenedesmus bijuga (G)		44,520
Scenedesmus quadricauda (G)		44,520
Scenedesmus armatus (G)		29,680
Closteriopsis longissima (G)		14,840
Oscillatoria spp. (BG)		630,700
Ulothrix spp. (G)		118,720
Aphanizomenon flos-aquae (BG)		422,940
Anabaena spp. (BG)		29,680
Nitzschia spp. (D)		29,680
Melosira granulata (D)	118,720	629,990
		4,592,000

APPENDIX

Table 18

Phytoplankton Composition

Station PL-5, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Tetrastrum sp. (G)		7,420
Pediastrum spp. (G)		7,420
Coelastrum sp. (G)		74,200
Gloeocystis sp. (G)		7,420
Tetraëdron lunula (G)		7,420
Stephanodiscus sp. (D)		3,710
Oocystis borgei (G)		29,680
Coscinodiscus spp. (D)		44,520
Cyclotella spp. (D)		40,810
Oocystis solitaria (G)		3,710
Chlamydomonas spp. (F)		29,680
Cryptomonas spp. (F)		33,390
Oscillatoria spp. (BG)		11,130
Scenedesmus abundans (G)		55,650
Nitzschia sp. (D)		7,420
Ulothrix sp. (G)		11,130
Melosira granulata (D)	166,950	638,120
Closteriopsis longissima (G)		3,710
Crucigenia sp. (G)		7,420
Golenkinia radiata (G)		3,710
Microcystis aeruginosa (BG)		7,420
Tetraëdron caudatum (G)		3,710
Cosmarium sp. (G)		3,710
Gomphosphaeria sp. (BG)		3,710
Dictyosphaerium pulchellum (G)		3,710
		1,049,000

APPENDIX

Table 19

Phytoplankton Composition

Station PL-6, Locust Point
24 October 1969

Organism	No. of Colonies	Cells per Liter
Coelastrum sp. (G)		5,562
Pediastrum duplex (G)		927
Peridinium sp. (F)		2,781
Coscinodiscus sp. (D)		22,248
Cyclotella spp. (D)		40,788
Oscillatoria spp. (BG)		31,518
Dictyosphaerium pulchellum (G)		10,197
Melosira granulata (D)	137,196	643,338
Ankistrodesmus falcatus (G)		6,489
Anabaena sp. (BG)		927
Scenedesmus spp. (G)		31,518
Ulothrix sp. (G)		2,781
Flagellates (F)		50,058
Staurastrum sp. (G) (desmid)		927
Anabaena circinalis (BG)		927
Pediastrum simplex (G)		927
Aphanizomenon flos-aquae (BG)		2,781
Oocystis sp. (G)		16,686
		871,000

Note: Lots of Detritus.

APPENDIX

Table 20

Phytoplankton Composition

Station PL-7, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Nephrocytium sp. (G)		5,565
Cystodinium sp. (F)		11,130
Navicula sp. (D)		5,565
Merismopedia sp. (BG)		3,710
Coscinodiscus rothii (D)		270,830
Cyclotella spp. (D)		183,645
Stephanodiscus niagarae (D)		1,855
Oocystis sp. (borgei?) (G)		92,750
Chlamydomonas spp. (F)		53,795
Cryptomonas spp. (F)		358,015
Mallomonas sp. (F)		24,115
Peridinium sp. (F)		16,695
Ankistrodesmus sp. (G)		14,840
Scenedesmus abundans (G)		70,490
Scenedesmus quadricauda (G)		51,940
Scenedesmus dimorphus (G)		16,695
Scenedesmus incrassatulus (G)		12,985
Scenedesmus bijuga (G)		5,565
Scenedesmus arcuatus (G)		1,855
Gloeocystis sp. (G)		16,695
Gomphosphaeria spp. (BG)		27,825
Pediastrum spp. (G)		127,995
Dictyosphaerium spp. (pulchellum, ehrenbergianum) (G)		152,110
Coelastrum spp. (G)		33,390
Tetraëdron sp. (G)		11,130
Coelosphaerium sp. (BG)		1,855
Actinastrum hantzschii (G)		5,565
Euglena sp. (F)		7,420
Anabaena sp. (BG)		5,565
Oscillatoria spp. (BG)		283,815
Ulothrix spp. (G)		64,925
Tribonema sp. (G)		12,985
Nitzschia spp. (D)		25,970
Aphanizomenon sp. (BG)		16,695
Melosira granulata (D)	40,810	185,500
Fragilaria capucina (D)	1,855	48,230
		2,229,000

APPENDIX

Table 21

Phytoplankton Composition

Station PL-8, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Tetrastrum spp. (G)		40,810
Golenkinia radiata (G)		7,420
Staurastrum sp. (G) (desmid)		7,420
Microcystis aeruginosa (BG)		7,420
Nitzschia sp. (D)		22,260
Chroococcus limneticus (BG)		3,710
Crucigenia sp. (G)	3,710	14,840
Tetraëdron trigonum (G)		3,710
Coscinodiscus rothii (D)		233,730
Oocystis borgei (G)		51,940
Cryptomonas spp. (F)		289,380
Cyclotella spp. (D)		85,330
Chlamydomonas spp. (F)		178,080
Ankistrodesmus falcatus (G)		122,430
Peridinium sp. (F)		14,840
Mallomonas sp. (F)		18,550
Scenedesmus quadricauda (G)		148,400
Scenedesmus abundans (G)		118,720
Scenedesmus bijuga (G)		74,200
Scenedesmus dimorphus (G)		25,970
Pediastrum spp. (G)		70,490
Coelastrum sphaericum (G)		81,620
Coelastrum microporum (G)		3,710
Gloeocystis sp. (G)		22,260
Tetraëdron lunula (G)		51,940
Schroederia judayi (G)		11,130
Gomphosphaeria spp. (BG)		37,100
Dictyosphaerium pulchellum (G)		63,070
Dictyosphaerium ehrenbergianum (G)		14,840
Closteriopsis longissima (G)		7,420
Stephanodiscus niagarae (D)		11,130
Anabaena spp. (BG)		11,130
Aphanizomenon flos-aquae (BG)		148,400
Ulothrix spp. (G)		285,670
Oscillatoria spp. (BG)		129,850
Melosira binderana (D)	22,260	51,940
Melosira granulata (D)	63,070	586,180
Fragilaria capucina (D)	37,100	415,520
Kirchneriella sp. (G)		7,420
Aphanocapsa sp. (BG)		3,710
Cystodinium sp. (F)		11,130
Coelastrum reticulatum (G)		7,420
Tetraëdron caudatum (G)		3,710
Scenedesmus acutiformis (G)		7,420
Sorastrum spinulosa (G)		7,420
		3,520,000

APPENDIX

Table 22

Phytoplankton Composition

Station PL-9, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Staurastrum sp. (G)		18,550
Closteriopsis longissima (G)		14,840
Tetraëdron caudatum (G)		7,420
Cystodinium sp. (F)		11,130
Sorastrum spinulosa (G)		3,710
Coscinodiscus rothii (D)		207,760
Tetraëdron lunula (G)		85,330
Chlamydomonas spp. (F)		126,140
Scenedesmus abundans (G)		152,110
Scenedesmus quadricauda (G)		66,780
Scenedesmus bijuga (G)		37,100
Scenedesmus dimorphus (G)		22,260
Oocystis spp. (G)		55,650
Cryptomonas spp. (F)		307,930
Cyclotella spp. (D)		48,230
Ankistrodesmus falcatus (G)		22,260
Peridinium sp. (F)		7,420
Mallomonas sp. (F)		18,550
Tetrastrum spp. (G)		44,520
Pediastrum spp. (G)		122,430
Coelastrum sphaericum (G)		40,810
Stephanodiscus niagarae (D)		3,710
Gloeocystis major (G)		11,130
Dictyosphaerium pulchellum (G)		63,070
Gloeocystis sp. (G)		22,260
Gomphosphaeria sp. (BG)		3,710
Ulothrix spp. (G)		278,250
Aphanizomenon flos-aquae (BG)		144,690
Oscillatoria spp. (BG)		63,070
Melosira granulata (D)	59,360	382,130
Fragilaria pinnata (D)	3,710	44,520
Fragilaria capucina (D)	37,100	482,300
Nitzschia sp. (D)		3,710
Schroederia judayi (G)		3,710
Merismopedia sp. (BG)		3,710
Golenkinia radiata (G)		3,710
Scenedesmus armatus (G)		14,840
		2,949,000

APPENDIX

Table 23

Phytoplankton Composition

Station PL-10, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Gloeocystis sp. (G)		22,260
Merismopedia sp. (BG)		5,565
Microcystis aeruginosa (BG)		14,840
Staurastrum sp. (G)		5,565
Dimorphococcus sp. (G)		5,565
Lagerheimia longiseta (G)		3,710
Tetraëdron sp. (G)		1,855
Aphanocapsa sp. (BG)		9,275
Melosira binderana (D)	1,855	9,275
Crucigenia sp. (G)		11,130
Chroococcus limneticus (BG)		1,855
Chlamydomonas sp. (F)		27,825
Oocystis solitaria (G)		11,130
Oocystis sp. (G)		20,405
Scenedesmus abundans (G)		50,085
Scenedesmus dimorphus (G)		12,985
Scenedesmus quadricauda (G)		20,405
Scenedesmus incrassatulus (G)		20,405
Cryptomonas spp. (F)		87,185
Peridinium and other flagellates (F)		12,985
Ankistrodesmus falcatus (G)		20,405
Cyclotella spp. (D)		152,110
Coscinodiscus rothii (D)		79,765
Melosira granulata (D)	24,115	144,690
Schroederia setigera (G)		11,130
Dictyosphaerium spp. (pulchellum, ehrenbergianum) (G)		53,795
Pediastrum spp. (G)		51,940
Coelastrum spp. (G)		44,520
Nitzschia spp. (D)		27,825
Gomphosphaeria sp. (BG)		11,130
Diatoma vulgare (D)		1,855
Oscillatoria spp. (BG)		187,355
Ulothrix spp. (G)		64,925
Aphanizomenon flos-aquae (BG)		57,505
Anabaena sp. (BG)		11,130
Tribonema spp. (G)		33,390
Fragilaria capucina (D)	12,985	211,470
Cystodinium sp. (F)		3,710
Stephanodiscus niagarae (D)		1,855
Actinastrum hantzschii (G)		1,855
Schroederia judayi (G)		1,855
Stephanodiscus sp. (D)		3,710
Closterium sp. (G)		1,855
Fragilaria intermedia (D)	1,855	70,490
		1,404,000

APPENDIX

Table 24

Phytoplankton Composition

Station PL-11, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Nephrocytium sp. (G)		3,710
Gomphosphaeria sp. (BG)		5,565
Lagerheimia longiseta (G)		1,855
Schroederia judayi (G)		3,710
Stephanodiscus niagarae (D)		3,710
Scenedesmus dimorphus (G)		9,275
Scenedesmus armatus (G)		16,695
Actinastrum hantzschii (G)		5,565
Scenedesmus bijuga (G)		5,565
Scenedesmus quadricauda (G)		50,085
Scenedesmus abundans (G)		53,795
Coelastrum spp. (G)		40,810
Pediastrum spp. (G)		55,650
Gloeocystis sp. (G)		7,420
Anabaena spp. (BG)		37,100
Aphanocapsa sp. (BG)		3,710
Oocystis borgei (G)		44,520
Oocystis solitaria (G)		16,695
Ankistrodesmus falcatus (G)		25,970
Cryptomonas spp. (F)		220,745
Chlamydomonas spp. (F)		37,100
Dictyosphaerium pulchellum (G)		44,500
Coscinodiscus rothii v. subsalsa (D)		233,730
Stephanodiscus spp. (D)		27,825
Nitzschia sp. (D)		1,855
Navicula sp. (D)		5,565
Amphora ovalis (D)		1,855
Fragilaria crotonensis (D)	1,855	64,925
Fragilaria construens (D)	1,855	77,910
Fragilaria intermedia (D)	16,695	302,365
Melosira binderana (D)	3,710	11,130
Melosira granulata (D)	42,665	341,320
Oscillatoria spp. (BG)		70,490
Ulothrix spp. (G)		142,835
Tribonema spp. (G)		40,810
Aphanizomenon flos-aquae (BG)		79,765
Crucigenia sp. (G)	1,855	7,420
Cyclotella sp. (D)		7,420
Coelosphaerium sp. (BG)		1,855
Staurastrum sp. (G)		1,855
Chroococcus sp. (BG)		1,855
Closterium sp. (G)		3,710
Flagellates (F)		16,695
Surirella sp. (D)		3,710
		2,140,000

APPENDIX

Table 25

Phytoplankton Composition

Station PL-12, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Pediastrum simplex & P. duplex combined (G)		64,925*
Dictyosphaerium pulchellum (G)		20,405
Coelastrum spp. (G)		29,680
Staurastrum sp. (G)		5,565
Stephanodiscus niagarae (D)		5,565
Cosmarium sp. (G)		1,855
Closterium sp. (G)		1,855
Ankistrodesmus sp. (G)		1,855
Nitzschia sp. (D)		1,855
Surirella sp. (D)		3,710
Scenedesmus spp. (G)		98,315*
Cyclotella spp. (D)		40,810
Flagellates: Chlamydomonas, Peridinium, & Cryptomonas combined (F)		187,355
Coscinodiscus rothii v. subsalsa (D)		189,210
Oscillatoria spp. (BG)		42,665
Oocystis sp. (G)		22,260
Nephrocytium sp. (G)		1,855
Fragilaria crotonensis (D)	3,710	20,405
Synedra sp. (D)		3,710
Fragilaria intermedia & F. construens combined (DD)	11,130	365,435
Aphanizomenon flos-aquae (BG)		31,535
Melosira granulata (D)	40,810	393,260
Ulothrix sp. (G)		12,985
Tribonema spp. (G)		109,445
		1,656,000

*Lots of detritus, difficult to identify.

APPENDIX

Table 26

Phytoplankton Composition

Station PL-13, Locust Point
21 October 1969

Organism	No. of Colonies	Cells per Liter
Kirchneriella lunaris (G)		7,420
Kirchneriella elongata (G)		1,855
Crucigenia sp. (G)	3,710	22,260
Tetraëdron caudatum (G)		16,695
Microcystis aeruginosa (BG)		5,565
Staurastrum sp. (G)		7,420
Stephanodiscus sp. (D)		1,855
Actinastrum hantzschii (G)		3,710
Chlamydomonas spp. (F)		157,675
Cryptomonas spp. (F)		354,305
Oocystis spp. (G)		120,575
Coscinodiscus rothii (D)		64,925
Cyclotella spp. (D)		116,865
Ankistrodesmus falcatus (G)		129,850
Mallomonas spp. (F)		92,750
Peridinium spp. (F)		31,535
Scenedesmus abundans (G)		166,950
Scenedesmus quadricauda (G)		90,895
Scenedesmus dimorphus (G)		37,100
Scenedesmus bijuga (G)		14,840
Scenedesmus incrassatulus (G)		31,535
Gomphosphaeria lacustris (BG)		29,680
Melosira binderana (D)	3,710	22,260
Melosira granulata (D)	29,680	189,210
Pediastrum spp. (G)		105,735
Dictyosphaerium spp. (pulchellum, ehrenbergianum)(G)		105,735
Dimorphococcus lunatus (G)		5,565
Schroederia judayi (G)		12,985
Coelastrum spp. (mostly sphaericum) (G)		102,025
Gloeocystis spp. (G)		27,825
Merismopedia sp. (BG)		7,420
Closteriopsis longissima (G)		5,565
Tribonema spp. (G)		42,665
Aphanizomenon flos-aquae (BG)		146,545
Oscillatoria spp. (BG)		421,085
Ulothrix spp. (G)		278,250
Synedra sp. (D)		5,565
Nitzschia sp. (D)		12,985
Anabaena sp. (BG)		11,130
Fragilaria capucina (D)	24,115	866,285
Fragilaria crotonensis (D)	1,855	44,520
Scenedesmus arcuatus (G)		1,855
Chroococcus sp. (BG)		1,855
Cosmarium sp. (G)		3,710
Cystodinium sp. (F)		12,985
Closterium sp. (G)		3,710
		3,943,000

APPENDIX

Table 27

Phytoplankton Composition

Station PL-14, Locust Point
27 October 1969

Organism	No. of Colonies	Cells per Liter
Tetrastrum spp. (G)		29,680
Stephanodiscus niagarae (D)		3,710
Coelastrum reticulatum (G)		14,840
Chroococcus limneticus (BG)		3,710
Staurastrum sp. (G)		7,420
Merismopedia sp. (BG)		7,420
Golenkinia radiata (G)		3,710
Quadrigula lacustris (G)		3,710
Crucigenia sp. (G)	3,710	18,550
Sorastrum spinulosa (G)		3,710
Cryptomonas spp. (F)		333,900
Chlamydomonas spp. (F)		148,400
Oocystis spp. (G)		103,880
Scenedesmus quadricauda (G)		166,950
Scenedesmus abundans (G)		207,760
Scenedesmus dimorphus (G)		11,130
Scenedesmus armatus (G)		11,130
Coelastrum sphaericum (G)		92,750
Coscinodiscus rothii (D)		96,460
Cyclotella spp. (D)		100,170
Peridinium spp. (F)		63,070
Tetraëdron caudatum (G)		7,420
Tetraëdron lunula (G)		55,650
Dictyosphaerium pulchellum (G)		29,680
Pediastrum spp. (G)		74,200
Schroederia judayi (G)		11,130
Gomphosphaeria lacustris (BG)		18,550
Dictyosphaerium ehrenbergianum (G)		25,970
Mallomonas spp. (F)		33,390
Ankistrodesmus falcatus (G)		11,130
Gloeocystis sp. (G)		14,840
Gloeocystis major (G)		3,710
Aphanizomenon flos-aquae (BG)		322,770
Ulothrix spp. (G)		107,590
Tribonema spp. (G)		48,230
Anabaena sp. (BG)		3,710
Oscillatoria spp. (BG)		70,490
Nitzschia sp. (D)		11,130
Melosira binderana (D)	18,550	140,980
Fragilaria crotonensis (D)	11,130	89,040
Fragilaria pinnata (D)	11,130	482,300
Fragilaria capucina (D)	37,100	597,310
Melosira granulata (D)	25,970	230,020
Nephrocytium sp. (G)		3,710
Treubaria setigerum (G)		7,420
Kirchneriella sp. (G)		3,710
Closterium sp. (G)		7,420
		3,843,000

APPENDIX

Table 28

Phytoplankton Composition

Station PL-14, Locust Point
27 October 1969

Organism	No. of Colonies	Cells per Liter
Crucigenia spp. (G)	3,710	59,360
Sorastrum sp. (G)		7,420
Stephanodiscus niagarae (D)		11,130
Staurastrum sp. (G)		3,710
Closterium sp. (G)		7,420
Dictyosphaerium pulchellum (G)		11,130
Schroederia judayi (G)		3,710
Coscinodiscus rothii (D)		81,620
Cyclotella spp. (D)		77,910
Scenedesmus abundans (G)		215,180
Scenedesmus quadricauda (G)		51,940
Oocystis spp. (G)		74,200
Nitzschia spp. (D)		241,150
Cryptomonas spp. (F)		215,180
Ankistrodesmus falcatus (G)		18,550
Tetraëdron lunula (G)		51,940
Peridinium spp. (F)		25,970
Gomphosphaeria sp. (BG)		18,550
Coelastrum spp. (G)		55,650
Cystodinium sp. (F)		3,710
Tetrastrum sp. (G)		18,550
Pediastrum sp. (G)		22,260
Dictyosphaerium ehrenbergianum (G)		25,970
Aphanizomenon flos-aquae (BG)		122,430
Ulothrix sp. (G)		3,710
Oscillatoria spp. (BG)		122,430
Anabaena sp. (BG)		11,130
Melosira granulata (D)	144,690	363,580
Tetraëdron caudatum (G)		3,710
		1,929,000

APPENDIX

Table 29

Phytoplankton Composition

Station PL-16, Locust Point
28 October 1969

Organism	No. of Colonies	Cells per Liter
Golenkinia radiata (G)		11,130
Coscinodiscus rothii (D)		226,310
Merismopedia sp. (BG)		7,420
Euglena sp. (F)		3,710
Cyclotella spp. (D)		1,202,040
Scenedesmus bijuga (G)		81,620
Scenedesmus abundans (G)		122,430
Scenedesmus quadricauda (G)		40,810
Scenedesmus dimorphus (G)		37,100
Oocystis spp. (G)		122,430
Cryptomonas spp. (F)		263,410
Chlamydomonas spp. (F)		81,620
Peridinium spp. (F)		48,230
Mallomonas sp. (F)		18,550
Actinastrum hantzschii (G)		29,680
Dictyosphaerium pulchellum (G)		92,750
Coelastrum sphaericum (G)		74,200
Gomphosphaeria lacustris (BG)		44,520
Crucigenia sp. (G)		22,260
Staurastrum sp. (G)		14,840
Gloeocystis spp. (G)		29,680
Gloeocystis major (G)		11,130
Schroederia judayi (G)		14,840
Pediastrum spp. (G)		44,520
Ankistrodesmus falcatus (G)		14,840
Closterium sp. (G)		3,710
Oscillatoria spp. (BG)		1,035,090
Ulothrix spp. (G)		140,980
Aphanizomenon flos-aquae (BG)		289,380
Nitzschia spp. (D)		293,090
Anabaena spp. (BG)		25,970
Melosira spp. (D)	44,840	222,600
Tetrastrum sp. (G)		7,420
Aphanocapsa sp. (BG)		3,710
		4,682,000

APPENDIX

Table 30

Phytoplankton Composition

Station PL-17, Locust Point
29 October 1969

Organism	No. of Colonies	Cells per Liter
Selenastrum bibraianum (G)		1,855
Euglena sp. (F)		3,710
Merismopedia sp. (BG)		1,855
Mallomonas spp. (F)		33,390
Peridinium spp. (F)		31,535
Cryptomonas spp. (F)		250,425
Chlamydomonas spp. (F)		38,955
Cyclotella spp. (D)		560,210
Coscinodiscus rothii (D)		142,835
Oocystis spp. (G)		29,680
Oocystis solitaria (G)		9,275
Ankistrodesmus falcatus (G)		1,855
Scenedesmus bijuga (G)		11,130
Scenedesmus incrassatulus (G)		11,130
Scenedesmus quadricauda (G)		38,955
Scenedesmus dimorphus (G)		14,840
Scenedesmus abundans (G)		33,390
Coelastrum sphaericum (G)		38,955
Dictyosphaerium pulchellum (G)		33,390
Gomphosphaeria lacustris (BG)		27,825
Actinastrum hantzschii (G)		3,710
Gloeocystis sp. (G)		16,695
Schroederia judayi (G)		14,840
Pediastrum spp. (G)		24,115
Staurastrum sp. (G)		1,855
Crucigenia sp. (G)		7,420
Ulothrix spp. (G)		68,365
Aphanizomenon flos-aquae (BG)		35,245
Oscillatoria spp. (BG)		276,395
Anabaena sp. (BG)		9,275
Nitzschia sp. (D)		22,260
Melosira granulata (D)	27,825	122,430
Stephanodiscus niagarae (D)		1,855
		1,919,000

APPENDIX

Table 31

Phytoplankton Composition

Station PL-18, Locust Point
29 October 1969

Organism	No. of Colonies	Cells per Liter
Diatoma vulgare (D)		1,855
Coelastrum sp. (G)		24,115
Cystodinium sp. (F)		9,275
Nephrocytium sp. (G)		3,710
Actinastrum hantzschii (G)		9,275
Crucigenia sp. (G)		12,985
Gloeocystis sp. (G)		12,985
Coscinodiscus rothii (D)		94,605
Cyclotella spp. (D)		899,675
Dimorphococcus lunatus (G)		11,130
Dictyosphaerium pulchellum (G)		48,230
Ankistrodesmus falcatus (G)		25,970
Schroederia judayi (G)		11,130
Gomphosphaeria spp. (BG)		33,390
Chlamydomonas spp. (F)		153,965
Cryptomonas spp. (F)		228,165
Peridinium, Mallomonas and other flagellates (F)		46,375
Pediastrum spp. (G)		27,825
Scenedesmus bijuga (G)		24,115
Scenedesmus quadricauda (G)		46,375
Scenedesmus incrassatulus (G)		55,650
Scenedesmus dimorphus (G)		40,810
Scenedesmus armatus (G)		38,955
Oocystis spp. (G)		100,170
Oscillatoria spp. (BG)		487,865
Aphanizomenon flos-aquae (BG)		25,970
Ulothrix spp. (G)		61,215
Tribonema spp. (G)		38,955
Anabaena spp. (BG)		38,955
Melosira sp. (granulata?) (D)	5,565	40,810
Nitzschia spp. (D)		61,215
Synedra sp. (D)		3,710
Kirchneriella sp. (G)		7,420
Aphanocapsa sp. (BG)		1,855
Staurastrum sp. (G)		1,855
Stephanodiscus niagarae (D)		3,710
Tetraëdron sp. (G)		1,855
Chroococcus sp. (BG)		1,855
		2,738,000

APPENDIX

Table 32

Phytoplankton Composition

Station PL-19, Locust Point
29 October 1969

Organism	No. of Colonies	Cells per Liter
Cystodinium sp. (F)		7,420
Stephanodiscus niagarae (D)		5,565
Coelosphaerium naegelianum (BG)		5,565
Nitzschia sp. (D)		1,855
Coscinodiscus rothii (D)		111,300
Cryptomonas spp. (F)		168,805
Chlamydomonas spp. (F)		33,390
Peridinium and other flagellates (F)		42,665
Oocystis sp. (borgei?) (G)		57,505
Oocystis solitaria (G)		9,275
Pediastrum sp. (G)		18,550
Dictyosphaerium pulchellum (G)		50,085
Coelastrum spp. (G)		35,245
Gloeocystis sp. (G)		9,275
Scenedesmus incrassatulus (G)		24,115
Scenedesmus dimorphus (G)		31,535
Scenedesmus bijuga (G)		20,405
Scenedesmus quadricauda (G)		35,245
Scenedesmus abundans (G)		35,245
Scenedesmus armatus (G)		16,695
Gomphosphaeria sp. (BG)		9,275
Actinastrum hantzschii (G)		9,275
Cyclotella spp. (D)		806,925
Staurastrum sp. (G)		3,710
Closteriopsis longissima (G)		3,710
Oscillatoria spp. (BG)		458,185
Ulothrix spp. (G)		51,940
Tribonema sp. (G)		12,985
Anabaena spp. (BG)		12,985
Aphanizomenon flos-aquae (BG)		37,100
Melosira granulata (D)	40,810	218,890
Synedra spp. (D)		29,680
Navicula sp. (D)		18,550
Tetraëdron sp. (G)		3,710
Microcystis aeruginosa (BG)		5,565
Stephanodiscus sp. (D)		1,855
Selenastrum sp. (G)		1,855
Lagerheimia longiseta (G)		1,855
Schroederia judayi (G)		1,855
Meridion circulare (D)		1,855
Ankistrodesmus falcatus (G)		5,565
		2,417,000

APPENDIX

Table 33

Phytoplankton Composition

Station PL-20, Locust Point
29 October 1969

Organism	No. of Colonies	Cells per Liter
Pediastrum sp. (G)		20,405
Coscinodiscus rothii v. subsalsa (D)		42,665
Anabaena sp. (BG)		16,695
Stephanodiscus niagarae (D)		1,855
Schroederia sp. (G)		9,275
Nephrocytium sp. (G)		5,565
Coelastrum sp. (G)		14,840
Staurastrum sp. (G)		3,710
Actinastrum hantzschii (G)		5,565
Ankistroedesmus falcatus (G)		3,710
Closterium sp. (G)		3,710
Closteriopsis longissima (G)		7,420
Gomphosphaeria sp. (BG)		1,855
Stephanodiscus sp. (D)		1,855
Chroococcus sp. (BG)		5,565
Scenedesmus spp. (G)		83,475
Oscillatoria spp. (BG)		395,115
Aphanizomenon flos-aquae (BG)		96,460
Ulothrix sp. (G)		7,420
Melosira sp. (granulata?) (D)		12,985
Fragilaria intermedia (D)	1,855	14,840
Stephanodiscus spp. & Cyclotella spp. combined (DD)		601,020*
Flagellates: Cryptomonas, Peridinium, & Chlamydomonas combined (F)		135,415*
Dictyosphaerium pulchellum (G)		38,955
Oocystis spp. (G)		55,650
Synedra spp. & some Nitzschia (DD)		63,070*
Tribonema spp. (G)		25,970
		1,675,000

*Lots of detritus, very difficult to identify.

Table 2

Summary of October phytoplankton dominants

Station	Most Dominant	Second Dominant	Third Dominant
PL-1	Oscillatoria spp. (BG)	Aphanizomenon flos-aquae (BG)	Cyclotella spp. (D)
PL-2	Melosira granulata (D)	Cyclotella spp. (D)	Oscillatoria spp. (BG)
PL-3	Melosira granulata (D)	Oscillatoria spp. (BG)	Scenedesmus abundans (G)
PL-4	Cyclotella spp. (D)	Oscillatoria spp. (BG)	Melosira granulata (D)
PL-5	Melosira granulata (D)	Coelastrum spp. (G)	Scenedesmus abundans (G)
PL-6	Melosira granulata (D)	Flagellates (F)	Cyclotella spp. (D)
PL-7	Cryptomonas spp. (F)	Oscillatoria spp. (BG)	Coscinodiscus rothii (D)
PL-8	Melosira granulata (D)	Fragilaria capucina (D)	Cryptomonas spp. (F)
PL-9	Fragilaria capucina (D)	Melosira granulata (D)	Cryptomonas spp. (F)
PL-10	Fragilaria capucina (D)	Cyclotella spp. (D)	Melosira granulata (D)
PL-11	Melosira granulata (D)	Fragilaria intermedia (D)	Coscinodiscus rothii (D)
PL-12	Melosira granulata (D)	Fragilaria intermedia & F. construens (DD)	Coscinodiscus rothii (D)
PL-13	Fragilaria capucina (D)	Oscillatoria spp. (BG)	Cryptomonas spp. (F)
PL-14	Fragilaria capucina (D)	Fragilaria pinnata (D)	Cryptomonas spp. (F)
PL-15	Melosira granulata (D)	Nitzschia spp. (D)	Cryptomonas spp. (F) & Scenedesmus abundans (G)
PL-16	Cyclotella spp. (D)	Oscillatoria spp. (BG)	Nitzschia spp. (D)
PL-17	Cyclotella spp. (D)	Oscillatoria spp. (BG)	Cryptomonas spp. (F)
PL-18	Cyclotella spp. (D)	Oscillatoria spp. (BG)	Cryptomonas spp. (F)
PL-19	Cyclotella spp. (D)	Oscillatoria spp. (BG)	Melosira granulata (D)
PL-20	Stephanodiscus spp. & Cyclotella spp. (DD)	Oscillatoria spp. (BG)	Flagellates (F)